Earth Observing System

THE EARTH OBSERVER

A Bimonthly EOS Publication

March/April 2000 Vol. 12 No. 2

EDITOR'S CORNER

Michael King
EOS Senior Project Scientist

On March 31, Dr. Ghassem Asrar, NASA Associate Administrator for Earth Sciences, announced the selection of winning proposals for the University Earth System Science (UnESS) program. Of the twenty-four proposals submitted, NASA's Office of Earth Science will fund four innovative Earth system science investigation concepts for future development as complete spaceflight missions or secondary payload instruments. Under the terms of the competition, these UnESS proposals are funded at approximately $300 K each for a period of nine months, after which point two primary missions and one back-up will be selected for final implementation. The two primary missions will be funded at $15 M each. This program is aimed at fostering the development of the next generation of Earth system scientists, engineers, managers, and educators through hands-on student involvement in global Earth observations from the vantage point of space.

The four concepts chosen for further development are:

- The SPACE mission, proposed by Columbia University, would examine, from aboard the International Space Station, the scattering properties of clouds and aerosols over a two-year period.
- The THOR mission, proposed by the University of Alabama in Huntsville, hopes to examine in unprecedented detail the growth and decay of thunderstorms through continuous observations of lightning over the Americas and adjacent oceans. By placing a lightning-monitoring sensor on a weather geosynchronous satellite, the THOR team hopes to gain radical new insight into the formation and evolution of thunderstorms.
- The Coral Reef Ecosystem Spectro-Photometric Observatory, proposed by the University of Hawaii, would look at the health of coral reefs around the world. By using spaceborne spectral observations of the reefs, scientists hope to determine how climate change may be affecting these vital contributors to Earth's health.
- CIRRUS, proposed by the University of Wisconsin, Madison, would be an instrument flying aboard the International Space

Station to look at clouds and, in particular, cloud ice. Understanding cloud ice will greatly enhance our understanding of clouds and their role in the global climate system.

In addition to these four proposals, NASA will consider two other meritorious proposals in the area of sea-level height and wind speed and direction, using highly innovative technologies. The originators of those two proposals, from the University of Texas at Austin and the University of Colorado, Boulder, will be encouraged to work together to combine their mission concepts for NASA consideration during the final selection process.

NASA selected 'Aura' as the name for the EOS Chemistry spacecraft after a selection process was undertaken to determine a new, more descriptive name for this EOS mission. Nominations were solicited from the EOS Chemistry community; and each of the four science teams on the CHEM platform, the EOS Chemistry Project Office, and the EOS Project Science Office (including both Goddard and NASA Headquarters) voted on their preferences among 57 nominations. Aura, Latin for 'air, breath, or breeze' was selected as the number one choice, both because it signifies the information CHEM will obtain about the atmosphere, and because it forms a nice two-syllable Latin complement to the choice of 'Terra' and 'Aqua' made earlier for the other large observatories in the Earth Observing System.

The NASA Research Announcement (NRA) for supplementary activities to support the validation of measurements by EOS satellite sensors in the Aqua time frame is scheduled to be released on May 8. This NRA will solicit proposals for validation investigations in support of AIRS/AMSU/HSB and AMSR-E, in particular, with additional support for spectroscopy that can support Aura and other chemical constituent missions in the future. The schedule includes submission of proposals by July 13 and selection of investigations by November.

Finally, all Algorithm Theoretical Basis Documents (ATBDs) for the ACRIM III, AIRS/AMSU/HSB, AMSR-E, and SAGE III instruments, and the Data Assimilation Office were reviewed on March 14-15 by a visiting committee chaired by Prof. Steve Ackerman of the University of Wisconsin. A total of 23 ATBDs were reviewed. These documents, developed for each data product, consist of a detailed physical and mathematical description of the algorithm, variance or uncertainty estimates, and practical considerations, such as calibration and validation, exception handling, quality assessments, and diagnostics. These documents, together with earlier ones produced by other EOS instrument teams, are posted on the World Wide Web following revisions that result from the written reviews as well as panel report recommendations (see eospso.gsfc.nasa.gov/atbd/pg1.html).

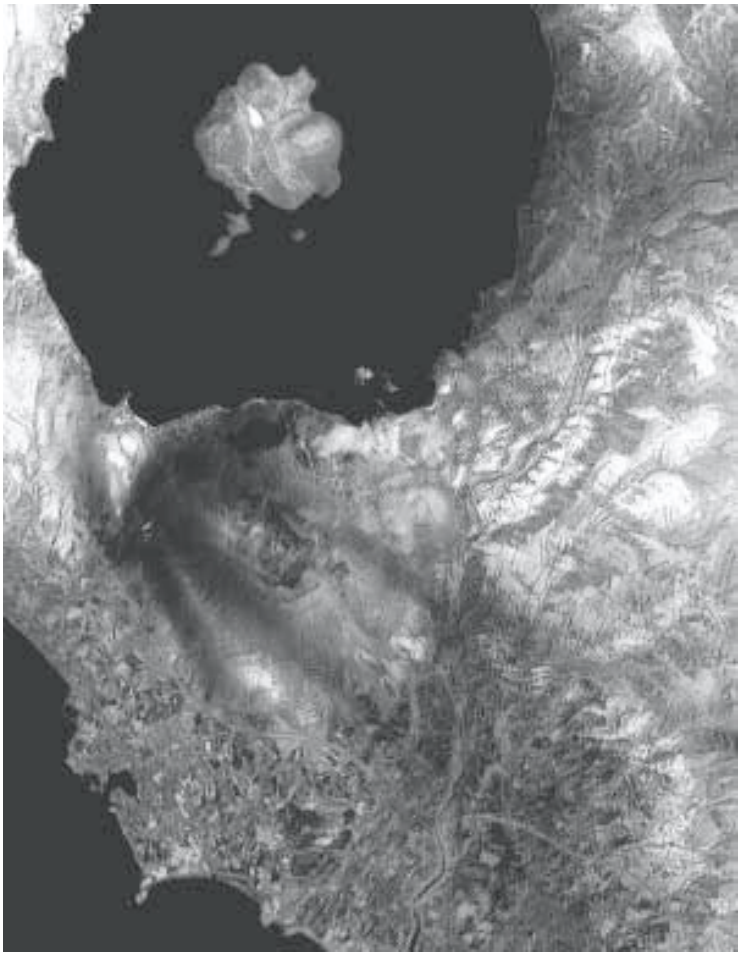


Image courtesy of MITI, ERSDAC, JAROS, and the U.S./Japan ASTER Science Team

On April 3, the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) on NASA's Terra satellite captured this image of the erupting Mt. Usu volcano in Hokkaido, Japan. The image is dominated by Lake Toya, an ancient volcanic caldera. The active Usu volcano is located near the south shore.

In this image, Mt. Usu is crossed by three dark streaks. These are the paths of ash deposits that rained out from eruption plumes two days earlier. The prevailing wind was from the northwest, carrying the ash away from the main city of Date. Ash deposited can be traced on the image as far away as 10 kilometers (6.2 miles) from the volcano.

Minutes of the Sixteenth Earth Observing System (EOS) Investigators Working Group (IWG) Meeting

— Renny Greenstone (renny.greenstone@gsfc.nasa.gov), Raytheon ITSS

The 16th meeting of the EOS Investigators Working Group (IWG) took place at the Hilton Tucson, East, in Tucson, Arizona, April 11-13, 2000.

Tuesday, April 11

Morning Plenary Session (Earth Science Enterprise/EOS Status)

Michael King, EOS Senior Project Scientist, Chair

Greeting the attendees by telecon, **Ghassem Asrar**, NASA's Associate Administrator for Earth Sciences, said that this was to be another truly exciting IWG meeting, and that he was sorry not to be able to attend in person to hear the latest results from the EOS investigators. He said in the next few days he would be reviewing both the 2001 and 2002 budgets.

He reminded the group of the four successful EOS launches of the past year. The Shuttle Radar Topography Mission (SRTM) was very successful, but it may be a year before the data become publicly available. There are about eight more science missions to come, with five of them involving international partners.

We are now entering a "data-rich" environment, and we need to get the data out to users. Pathfinder activities have started with the Department of Agriculture and the Federal Emergency Management Agency (FEMA).

EOSDIS is now functioning at the 90% level, and its development phase will end at the close of 2001. It is now providing full support to the Landsat mission.

The Earth Probes program now focuses on three small satellite missions. We are currently working on a small-satellite program.

Science and Technology has experienced the largest growth in our budget. It will have increased by about 25% by the 2005 time frame. Advanced technology will have to be more efficient than it has been in the past. There is to be a focus on component development and more-advanced data handling at the spacecraft.

After a decade the original plans for EOS are being questioned by its sponsors. A new Science Implementation Plan has been developed in response to this concern. It allows for the evolution of EOS using knowledge gained from the first phase.

Mark Schoeberl (Goddard Space Flight Center) is taking the lead on looking at EOS 20-30 years in the future. This long-term vision is necessary because we want to convey clearly that we are in this business for the long term. In the second decade, EOS will continue growth in *understanding* of climate. By the third decade, we will have developed the basis for *predicting* Earth's climate. Science continues to be the motivation for what we do, but we want to demonstrate its benefit to society.

Chris Scolese (Goddard Space Flight Center, GSFC) reviewed the "Status of the EOS Flight Program." Landsat 7 and Terra have been the two major mission successes. Landsat 7 data became available to the public in August 1999.

Terra has begun formation flying with Landsat 7. Preparations for calibration maneuvers are now under way. Scolese outlined the activities that led to an additional six weeks of mission activation time. Both the calibration and the inclination maneuvers remain to be done. Direct broadcast still has to be checked out—six ground sites are functioning so far.

Some mission status reports follow:

- The Terra mission control center is highly successful, and now the Polar Ground Network is of greatest concern. There needs to be a network expansion for additional missions such as Aqua and Aura (new name for the CHEM mission).
- Aqua is now on track for a December 2000 launch. An over-vibration of the B.F. Goodrich boards could have led to a delay, but we have recovered from that mishap.
- ICESat is to be launched on a Delta II along with CATSat. The engineering model of GLAS is in good shape.
- SORCE is now a PI-mode mission (as of October 1999).

- TIM is to fly on a Hitchhiker mission on the shuttle (in addition to the SORCE mission).
- NPP is the NPOESS Preparatory Project. It is projected to be ready in 2005 carrying at least three instruments, VIIRS, CrIS, and ATMS (replacing the AMSU and HSB/MHS instruments).
- Earth Observing satellites now operating are TRMM, ERBS, UARS, TOMS, Landsat 7, Terra, QuikScat, TOPEX/Poseidon, and ACRIMSAT. Landsat 7 operations are to be transferred to the U.S. Geological Survey (USGS) in 2001.

Scolese listed some challenges being faced by EOS:

- Budget impacts are due to:
  - delayed launch of Terra affecting ESDIS;
  - prior year budget cuts causing ESDIS to fall behind; and
  - possible delayed launch of Aura
- Other challenges to be met are:
  - need to step up Polar Ground Network;
  - uncertainties in Space Operations Management Organization (SOMO) budget and services;
  - current NASA emphasis on risk reduction could affect planned test programs—the immediate concern is for Aqua and ICESat. A report is expected by early summer, and additional testing may be recommended before launch.

Summarizing, Scolese said that the EOSDIS Core System (ECS) has clearly turned around and Aura stability has been established.

Next on the program was **Jack Kaye** (Director of the Research Division, Office of Earth Science [OES], NASA Headquarters), presenting the current status of "Earth Science Enterprise (ESE) Strategic Planning." The strategic plan is to be embodied in the NASA ESE Science Implementation Plan.

The Earth Science Enterprise Mission objective is to "develop a scientific understanding of the Earth system and its response to natural and human-induced changes to enable improved prediction of climate, weather, and natural hazards for present and future generations." Three goals are:

- Observe, understand, and model the Earth system to learn how it is changing, and the consequences for life on Earth.
- Expand and accelerate the realization of economic and societal benefits from Earth science, information, and technology.
- Develop and adopt advanced technologies to enable mission success and serve national priorities.

Elements of the first of the three goals are these:

- Discern and describe how the Earth is changing—*variability.*
- Identify and measure the primary forcings on the Earth system from human activities—*forcing*.
- Determine how the Earth system responds to natural and human-induced changes—*response.*
- Identify the consequences of change in the Earth system for human civilization—*consequences.*
- Enable the prediction of changes in the Earth system that will take place in the future—*prediction.*

(The five terms in italics above summarize the heart of the scientific questions to be addressed by the ESE.)

Elements to be considered in evaluating "program balance" are: basic research and data analysis, systematic missions, exploratory missions, and operational precursor and technology demonstration missions.

NASA has five Earth science research themes that are mostly consistent with USGCRP themes and recommendations of the NRC Pathways Report:

- Biology and Biogeochemistry of Ecosystems and the Global Carbon Cycle
- Atmospheric Chemistry, Aerosols, and Solar Radiation
- Global Water and Energy Cycle
- Oceans and Ice in the Earth System
- Solid Earth Science

Kaye pointed out that there are now three phases defined for EOS Program Implementation:

- *Near-term* runs from 1999 to 2002 and includes the first series of EOS spacecraft and the ESSPs
- *Mid-term* runs from 2003 to 2010 and includes launch follow-ons to the first EOS series plus full initiation of NPOESS for long-term observation of many parameters
- *Long-term* is the period beyond 2010. It is the period where we begin to implement the ESE "Vision."

Commercial partnership (data buy) missions are to be considered where appropriate.

Kaye summed up, saying that ESE has a research program that is designed to answer societally important questions. Prioritization criteria have been developed, and a hierarchy of science questions has been developed and prioritized within different areas—Variability, Forcing,

Response, Consequences, and Prediction.

In a Q and A period, Kaye said that the 2001 budget has $5 M for carbon cycle research. It will be in a forthcoming NRA. Weather is now in the ESE program in response to a perceived need for better coupling between NASA and the operational agencies. There is a concern that the operational agencies may not be prepared to do the needed follow-up.

Vanessa Griffin (GSFC) gave a flying tour of the "EOS Data Processing System and Data System Status." She started by pointing to the successful support now being given to Landsat 7 and to Terra. The Aqua Mission Planning Review was held on March 7 and 8. They are currently upgrading the ingest system for Landsat 7. Orders for Landsat 7 scenes have jumped to over 75 per day.

Level 1 processing for the Terra instrument products is in the range of 73 percent to 91 percent (CERES). MISR Level 1 processing is well behind at about 22 percent, but this is as planned. MISR has an unusally complex software architecture.

Problems with end-to-end data flow are related to "bit flips" and to some inefficiencies at EDOS. There have been system outages at EDOS and at the DAACs. Reprocessing of data has shown great improvement since the time the instrument covers were opened. The EOSDIS Core System (ECS) has met the cal/val needs of the instrument teams.

Yoram Kaufman (Terra Project Scientist, GSFC) enthusiastically led a "dry run" presentation of Terra progress for a press briefing scheduled to take place on April 19. Each of the PIs for the five Terra instruments followed with short overviews of their instruments. (Co-I John Gille gave the MOPITT overview, substituting for PI Jim Drummond.) Wrapping up, Kaufman showed that MODIS data over the Caribbean made it possible to detect smoke over both land and ocean even though final calibrations had not yet been made.

Teruyuki Nakajima (University of Tokyo), leader of the GLI instrument team for the ADEOS II mission, discussed "Japanese Space Program Activities." He described his presentation as an "overview by a scientist." He gave several examples to show that the Japanese space program is considerably smaller than the U.S. program, pointing out that the NASDA budget was about 1/6 of the NASA budget in 1999. He said that the Japanese space program needs restructuring. It went too fast from the time of the MOS-1 mission to ADEOS II.

ADEOS II has now suffered a two-year delay with anticipated launch now set for November 2001. MOS 2 has been cancelled, and MOS 3 *may* also be cancelled. There is a concern with post-2006 satellite coverage.

Nakajima gave some examples of Japanese space-based results:

- Land-surface backscatter observations from the PR instrument on TRMM have brought out vegetation patterns.
- Analysis of aerosols from the OCTS instrument observations from 1996 and 1997 have given optical thickness and size indices for aerosols.
- Aerosol data from TOMS have been used to distinguish soils, dust, smoke, sulfates, and sea salt.
- Aerosol and cloud particle coverage have been related.
- The Japanese have performed shipborne aerosol studies and will provide shipborne MODIS validation.

Afternoon Plenary Session

First speaker of the afternoon was **John Townshend** (University of Maryland) on the subject of "The Federation of Earth Science Information Partners (ESIPs)." Townshend reviewed the beginnings of the ESIP concept. At an earlier review, held at La Jolla, there had been a suggestion that a federation of science users could complement the government's effort. In organizing the Federation, it was recognized that there was a need to share governance among all the types of ESIPs.

Townshend explained that there are three types of ESIPs: Type 1 are the DAACs; Type 2 are experimental (they emphasize creativity for users who want scientific information); and Type 3 are for general users including education and outreach.

The ESIPs are very heterogeneous. Their levels of funding vary widely. They are expected to use the best scientific practices.

Type 2 ESIPs include those with orientations toward oceanography, terrestrial surface, climate, technology, and public health. They have been funded since March 1998.

Type 3 ESIPs include those dedicated to educational outreach, new products and services, regional foci, and legal foci. The University of Maryland ESIP acts as a global land-cover facility. New services include facilitating integrated data use.

ESIPs are organized into committees, working groups, and clusters. Their organizations may be either formal or informal. Townshend referred to one of the clusters as a content-based search/data mining cluster. As a next step there is to be a more-formal constitution and agreed-to bylaws.

There are many indicators of success. In Townshend's words "we have evolved into a much more diverse 'ecosystem' for providing products and services." Examples of reaching wider audiences include the NBC4 (Washington DC metro area) television channel's use of NASA data, and a program called "Museums Teaching Planet Earth," headed jointly by Rice University and the Houston Museum of Natural Sciences. An Upper Midwest Consortium has users who are farmers and other local interests.

Lessons learned include: one size does not fit all, and "one-stop shopping" has been replaced by "one-mall shopping."

Gary Johnson (Stennis Space Center) discussed the "Regional Earth Science Applications Centers (RESACs)." The program was started in February 1999 with an original nine centers, now reduced to seven through mergers. The RESACs are to engage in key regional issues. Alex Tuyahov of NASA Headquarters is the technical monitor of the program.

As one example, Johnson discussed the Northern Great Plains RESAC, which focuses on providing data to farmers, foresters, ranchers, and the like. Johnson agreed that RESACs and ESIPs can be very much alike with overlaps existing. Where desirable the two groups coordinate their activities.

"EOS Validation Activities" was the subject of a talk by **David Starr** (GSFC)**.** He outlined his talk, saying that he would give an overview of Definition and Process, the status of Aqua and Aura validation, and a whirlwind tour of Terra validation.

The whirlwind tour included his discussion of validation team initiation activities, station and network correlative data, and six field experiments. Starr described the MOBY buoy ocean validation effort, saying that the week following the meeting there would be ER-2 overflights. He showed the distribution around the world of various validation test sites. There are biweekly aircraft flights for profiles of CO, CO_2, and CH_4. He noted that there is little heritage for the CO measurements from space (MOPITT). The site run by Rachel Pinker in Nigeria shows the effect of biomass burning.

The ARM/CART site is a very important contributor to the validation effort. The Raman lidar provides many major constituent profiles including those for water vapor and aerosols. The site is a key source for validation of cloud optical-depth retrievals and also provides Raman lidar cloud measurements. Cloud observations include the great variety of ice crystal sizes and shapes to be found in cirrus clouds.

Paul Simon (Institute for Aeronomy of Belgium) gave the "ESA Earth Science Program Status Report." Current elements of ESA's Earth science program are classified as "A" and "B." The A element consists of individual optional missions, which are Meteosat, ERS-2, ENVISAT, and METOP (with EUMETSAT). (Optional missions are proposed missions for which 15 member nations are free to subscribe.) The B element is covered by the Earth Observations Envelope program, including Earth Exploring Missions (science driven) and Earth Watch Missions (applications driven). Simon noted that Earth science missions are part of the Applications Program.

Simon briefly reviewed the various missions. METOP has both a METEO package and an ESA package. IASI is an Announcement of Opportunity instrument.

The "Envelope Program" includes funding for an Earth Explorer mission and development and exploration. Apart from implementation of Earth Watch Missions, most ESA Earth observations should be covered by one "optional" program.

Earth Explorer Missions include core missions (major) and opportunity missions (smaller).

The GOCE is a gravity-field mission and is also intended to derive the Earth's geoid. It will do gradiometry with satellite-to-satellite tracking.

The Atmospheric Dynamics Mission (ADM) will lead to improvement in climate and weather models and will carry a doppler wind lidar. The winds will be measured with 500-meter vertical resolution up to two kilometers.

The Cryosat Mission will determine variations in thickness of polar ice sheets and of floating sea ice as well. It will use a radar altimeter operating in Ku band in three operational modes.

The SMOS mission will measure soil moisture and ocean salinity using an L-band 2D interferometer. This is a passive microwave radiometer operating at 1.4 GHz.

The ACE mission will use GPS soundings to determine temperature and humidity profiles.

Earth Explorer Missions include COALA—determining ozone by stellar occultation; SWARM—measuring Earth's magnetic field; and SWIFT—determining stratospheric winds by Doppler interferometry.

Wednesday, April 12

Morning Plenary Session (Land Processes and Terrestrial Carbon Cycle Science)

Steve Running (University of Montana**), Eric Wood (**Princeton University), Co-Chairs

Lead-off speaker this morning was **Soroosh Sorooshian** (University of Arizona) on the subject of "Arid Land Hydrology and Water Resources." Sorooshian said that the goal of his project was to improve the understanding of the hydrologic cycle and its complex mechanisms. Fifty-three percent of the continental land mass is semi-arid, with precipitation less than 400 mm/yr.

After giving the general picture, Sorooshian went on to discuss the hydrology of the Southwest U.S. His group has developed an artificial neural network capability called PERSIANN that makes estimates of precipitation at 1° by 1° resolution. Sorooshian showed examples of rainfall from the summer monsoon (July to September) and winter snow accumulation from mid-latitude cyclones.

The group has a six-hour global precipitation product, and a three-layer model for snow depth vs. time. They have been assimilating the GOES Cloud Image product into a mesoscale model, leading to improvements in the RAMS model.

In the future Sorooshian's group will focus on monitoring and prediction of water distribution and availability, particularly to develop improved short-term forecasts using their mesoscale model. In doing this they will apply NCEP/eta forcing. They plan to have results that will be on the scale needed by users.

Sorooshian ended his talk with a few examples of groundwater decline in Pima County. Groundwater decline has led to significant subsidence of the land surface. Despite water-shortage problems there is a forecast for continued significant population growth in the affected southwestern states.

Dennis Lettenmaier (University of Washington) presented "Hydrologic Simulations of High Arctic Rivers." He began with some general observations: Most of Arctic drainage takes place in Russia and Canada. There are five major rivers in the Russian part of the drainage area. Runoff ratios (Runoff to Precipitation, R/P) are generally considerably higher there than in other parts of the globe. Interestingly, 60% of the Arctic drainage basin lies south of 60° N. In North America snow is a disproportionately significant factor in the annual runoff. (About 30% of precipitation occurs as rainfall, but most ends up as evapotranspiration.)

Lettenmaier gave the current status of high-latitude macroscale hydrologic modeling. Much of the work focuses on small catchments where it is easier to do the research. The complexity of the actual processes is not well represented. The best quality data are still needed. A wealth of unmined data still exists in Russia.

"Progress Towards a Global Biospheric Forecasting Capability" was addressed by **Ramakrishna Nemani** (University of Montana). He subtitled his talk "Prospects and Progress." Biospheric forecasting is the prediction of future states of biospheric variables in response to projected atmospheric conditions. The goal is to provide objective analyses of possible ecosystem responses, leading to better socio-economic decisions.

Nemani described an integrated modeling system leading to fluxes of carbon, nitrogen, and water. His group has done simulations with resolutions down to 30 meters. They use the Internet to get weather data on an hourly basis. They also get data on solar irradiance. Possible forecast outputs are phenology, soil moisture, fire danger, and crop/range productivity.

Nemani noted that the wine industry in Napa Valley is very sensitive to short-term climate change. The growers tend to use one-to-three-day forecasts. They treat their vines in terms of "blocks." They want to maintain a constant stress on the vines. Irrigation is their key tool, and they use LAI to decide on irrigation needs. Much of the rainfall in the study region depends on the Pacific Decadal Oscillation (PDO), which is now in its positive phase. It is not known when there will be a change to the negative phase.

Alfredo Huete (University of Arizona) reviewed "Advanced Vegetation Indices from MODIS." MODIS vegetation indices are available globally at one kilometer and regionally at 250 and 500 meters. There are 16-day and monthly indices. The well-known NDVI is used to make classifications into water, arid, semi-arid, grass, conifer forests, and deciduous forests. Huete showed a soil-adjusted vegetation index (SAVI) and also showed VI, which is self-adjusting for atmospheric characteristics. His work has led to the development of the Enhanced Vegetation Index (EVI), which takes blue bands into account, thus minimizing aerosol contributions to the index. He showed compositing to take into account scan-angle and sun-angle effects.

Jing Chen (Canada Centre for Remote Sensing) talked about "New Landcover and Leaf Area Index Mapping for Canada." He said that his work involved

pixel-based net ecosystem productivity of Canadian forests using historical climate and disturbance data. He defined Net Ecosystem Productivity (NEP) and Net Biological Productivity (NBP). The methodological issues he is concerned with have to do with estimating the boreal carbon cycle. Sinks per area are small compared to Net Primary Productivity (NPP). There is a long carbon residence time, on the order of 50 years.

Approaches useful for addressing the issues include: relate soil carbon stocks to current NPP; apply comprehensive modeling to all factors known to affect the carbon cycle; and improve understanding of long-term processes. Chen uses an integrated "bottom-up" approach to take disturbances into account. He has found that a sunlit/shadowed leaf model is superior to a big-leaf model. He applies the Century model in his analyses.

He has concluded that Canadian forest areas are a carbon sink, although there is large spatial variability and a considerable north-south gradient. The effect of global warming will be to make the Canadian forests more of a carbon sink.

Overall he concludes that it is now computationally feasible to conduct regional process-based modeling of the carbon cycle using satellite images. Issues of the spatial distribution of carbon can be resolved, including identifying sources and sinks and determining long-term trends. Maps of forest-stand age will be useful.

Dave Keeling (Scripps Institution of Oceanography) gave an update on "Evidence of Interannual Variability in Terrestrial Carbon Fluxes Deduced from Atmospheric Isotopes of CO_2." The C_{13}/C_{12} ratio that has been measured for over 20 years is sensitive to the terrestrial type carbon but it is confounded by fossil fuels. The flux exchanges between the atmosphere and the biosphere have turned out to be larger than expected.

There is a big temperature effect modifying the carbon fluxes. He pointed to the 0.8°C global temperature rise over the last 100 years and added that temperatures since 1980 have been higher than they have ever been in tens of thousands of years.

The annual seasonal cycle in the C_{13}/C_{12} ratio mirrors the rise in carbon. Keeling used a zonal inversion model with 1986 data to examine the zonally averaged CO_2 exchange with the terrestrial biosphere and oceans. He finds that the tropical zones show large sources of carbon and that temperate zones are carbon sinks. He finds relations between temperature changes, precipitation changes, and carbon-dioxide changes.

Keeling was followed by **Inez Fung** (University of California at Berkeley), whose retitled subject was "The Science of Carbon Sequestration: a Survey of Carbon Cycling." Fung said that her perspective on C_{13} differed from Keeling's. She has found that C3 and C4 plants have different effects on C_{13}, therefore accounting for less of a sink than Keeling has proposed. She has found a steady increase in NDVI in recent decades (1982-1998) with the exception of the Mt. Pinatubo years.

Fung provided a comparison of carbon amounts with the Southern Oscillation Index (SOI). She found that warmer falls mean enhanced decomposition, thus carbon release, and warmer springs mean enhanced carbon uptake (photosynthesis). She said that carbon-dioxide fertilization may lead to enhanced photosynthesis.

Another area of interest is iron. She has looked at dust emission as it varies from natural or disturbed soils. Fine aerosol particles come from disturbed soils. About half of the dust in the atmosphere is due to *recent* disturbances. She has developed an iron stress index and has looked at the Fe/N ratio. From her data she has concluded that deposition of dust in the oceans has long-term consequences for carbon dioxide in the atmosphere. The carbon-dioxide sinks of today may not be the carbon-dioxide sinks of tomorrow.

In the future it will be important to study how the carbon-dioxide growth rate and the climate change evolve. Ultimately, we will have to take into account DMS (dimethyl sulfide) as well.

Wednesday Afternoon Plenary Session (Atmospheric Processes and Chemistry—TRMM, GOME, TOMS, and SOLVE Science Activities)

Mark Schoeberl (GSFC) Chair

The lead speaker of the afternoon was **Boris Khattatov** (National Center for Atmospheric Research), who reviewed "Inverse Modeling of the CO Budget: Building Blocks, Progress, and Problems." Khattatov said that he would be talking about prior work since his EOS activities were not yet under way. His main goal has been to combine observations with models. He calls his model MOZART 2 (Model for Ozone and Related Tracers). The model takes into account 56 chemicals and has T42 resolution with 31 levels.

His many data sources have or will include MAPS, MOPITT, IMG (CO), SAFARI 2000, NOAA CMDL, and GOME O_3. He pointed out that available measurements are sparse and irregular. Models have to rely on poorly known quantities, e.g., surface emissions. His task has been to map the observations to regular time and space grid points. He uses 3D sequential assimilation with maximum-likelihood estimation.

In carrying out sequential assimilation he has used ozone data from MLS on UARS. The analysis is performed for half-hour intervals. The technique has worked well with synthetic MOPITT data. A regional model for Indonesia has also worked rather well.

In discussing CMDL CO inversions, Khattatov said that he uses the IMAGES model with 33 source regions representing the whole globe. IMAGES is a simple model that allows derivation of surface emissions.

In a summary of his talk, Khattatov said that the relation between emission and concentrations is nonlinear, due to reactions with OH and other chemical species.

Chairperson, **Mark Schoeberl** (GSFC), gave the history of "The SAGE III Ozone Loss and Validation Experiment (SOLVE)." In the experiment he used data from POAM on the SPOT spacecraft as the surrogate for SAGE III (not yet launched). The purpose of the investigation was to examine northern hemisphere polar stratospheric ozone loss with new tools now available. Data were supplied by NASA's ER-2 and DC-8 aircraft, as well as balloons. The balloons carried either remote- or *in situ*-sensing payloads. Ground-based data came from Kiruna, Sweden.

Polar Stratospheric Clouds (PSCs) are the key to ozone destruction in the stratosphere. In his experiment a wide variety of such clouds was observed. Some of the Nitric Acid Trihydrates (NATs) that were observed were found to be larger (~ 20 μm) and warmer than expected. Also, some of the observed PSCs were at lower elevations than expected and warmer than expected. Schoeberl reviewed the chemistry involving PSCs and demonstrated the denitrification process.

During the experiment the DC-8 flew through the plumes that were emitted from the Hekla volcanic eruption in Iceland. Repairs of the resulting engine damage were estimated to cost about $3 M, although the damage did not stop the aircraft observations.

In conclusion, Schoeberl said that SOLVE had shown that there is no evidence for heterogeneous chemical processing by high cold cirrus, and that all chlorine budget components checked out with laboratory measurements.

Last speaker before the afternoon break was **Kelly Chance** (Smithsonian Astrophysical Observatory) on the subject of "GOME Measurements of Formaldehyde." Formaldehyde in the atmosphere (HCHO) is a good indicator of biogenic activity. It serves as a proxy for tropospheric OH. GOME is the Global Ozone Monitoring Experiment and is onboard the ERS-2 spacecraft, which was launched in April 1995. HCHO is the most difficult of the atmospheric gases to retrieve from the GOME instrument.

In the future Chance will be looking at biomass burning events, CO/aerosol correlations, and tropospheric O_3/NO_2.

Following the break **Daniel Jacob** (Harvard University) gave a brief runthrough on the "The Global Monitoring of Tropospheric Chemistry." He said that the coupling of chemistry and atmospheric transport has become more important in the modeling community. At Harvard they have been using global 3D models of the troposphere in their research. The three models are CACTUS, Harvard-GEOS Model (chemical transfer model), and the Harvard-FSU model.

CACTUS focuses on tropospheric ozone. There has been an increase in the background since 1870 due to human activity. CACTUS uses the GISS GCM2 model and adds tropospheric chemistry. They find that the annual mean global radiative forcing due to ozone is ~0.44 W m^{-2}. The model is capable of resolving correlations with other forcings, e.g., clouds.

Sulfate aerosol forcings can also be considered in the model. Sulfates dominate at northerly latitudes. However, the current version of the model overestimates preindustrial ozone by about a factor of two. Thus, we are left with uncertainties about the natural source. We will need to make drastic changes in our assumptions if we are to match the observations.

Using outputs from the Harvard GEOS model, Jacob ended his presentation with two animations: One showed pulses of CO pollution traveling west to east at northern midlatitudes, and the other showed the progression of simulated ozone.

Thursday, April 13

Morning Plenary Session (Ocean Processes and Biology—QuikScat, SeaWiFS, and Other Oceanography Mission and Science Results)

Mike Freilich (Oregon State University), Chair

Bob Atlas (GSFC) discussed the "Impact of Scatterometer Wind Measurements on Numerical Weather Prediction." He began by reviewing the need for remotely sensed surface winds. Surface wind velocity estimates are used to drive ocean models, leading ultimately to improved numerical weather prediction (NWP). The conical design of the SeaWinds instrument allows it access to many spaceborne platforms. The coverage offered is also greater than that afforded by other designs. With SeaWinds 90% of the globe is covered in

24 hours. Atlas presented an image bringing out the coverage provided by SeaWinds: a cyclone and a front are both clearly defined in the image. Uniquely, SeaWinds data define the Intertropical Convergence Zone (ITCZ).

There are some problems however. Sometimes the ambiguity removal procedure gives incorrect results, and sometimes the warm front representation is too smooth.

QuikScat data have a greater impact in the southern hemisphere. They are more beneficial to 5-day forecasts. The impact on sea-level pressures is small, but still larger than the SSM/I or ERS impacts. With the new model function QuikScat data show a great improvement in the 5-day forecasts. With the GEOS-3 model forecasts, there are improved impacts on the 500-mb geopotential height forecasts for both northern and southern hemispheres.

All evaluations have shown potential for improvements from QuikScat, and further improvements in QuikScat data are being developed by JPL.

David Long (Brigham Young University) presented "Land/Ice Applications of SeaWinds." He emphasized polar applications of the data. There is a NASA Pathfinder set of SeaWinds data. Scattering cross section data, $\sigma_{0'}$ are available as browse images. A "lost" iceberg that had been missed by the National Ice Center was spotted uniquely in the SeaWinds data.

SeaWinds data have many applications: Brightening and darkening in the data reveal warming and cooling in the oceans as fronts pass by. Ice types can be classified using the fusion of passive/active sensors. There is a capability to determine katabatic (downslope) winds over the Antarctic regions. It has been possible to detect the onset of Arctic melting and detect the influence of warm fronts. The diurnal cycle in snow melt can be detected, as can the accumulation of snow in Greenland.

Examining the process of Amazon deforestation, Long showed a comparison of SeaSat (1978) data with NSCAT (1996) data. The comparison brought out areas of significant change.

Tim Liu's (JPL) topic was "High Resolution Wind Measurements in Hurricanes and Equatorial Waves." He started with a presentation on tropical instability waves. He showed winds and temperatures for 5-month periods at about 3°N, moving westward. Both winds and temperatures propagate together very well, and there are two applicable hypotheses as to why this happens. Of the two, Liu supports the boundary-layer (second) hypothesis.

Liu uses QuikScat for winds and TMI (on TRMM) for SST values. He said that QuikScat can pick up hurricanes before the National Hurricane Center does (using cloud observations). This can make a one-to-two-day lead possible.

Next Liu turned to flooding on the Indian subcontinent. He said that different scattering phenomena have different effects on polarization signals. Where there are floods the ratio VV/HH < 1, and in dry areas the ratio VV/HH > 1. The measurements are all for a single incidence angle.

Steve Nerem (University of Texas, Austin) reviewed "Variations in Global Mean Sea Level Observed During the TOPEX/Poseidon Mission." The center of mass of TOPEX is known to 2.5 cm. Altimetry measurements of sea level are good to ~3 or 4 cm overall. The spacecraft was launched in August 1992 and has a 10-day repeat cycle.

Here are some mission findings: A year-long effort has established the values of the ocean tides. Sea level has increased during the 1993-1999 period by about 20 mm. Readings from the Poseidon instrument onboard the spacecraft are lower than the TOPEX instrument readings. TOPEX readings show just a slight drift from tide gauge readings. Sea level peaked in 1998 during the El Niño. SSTs have peaked for each observed El Niño event. There is a very good correlation of sea level with SST. Most of the sea-level change occurs in the top few hundred meters. Sea level has been rising about 2.7 mm/yr, with error bars of about ± 0.5 mm/yr, in the period 1997-2000. TOPEX observed a 20-mm change in global mean sea level during the 1997-1998 ENSO event. We will still need long-term data sets to establish true climatic trends.

Following the Thursday morning break **Mary-Elena Carr** (Jet Propulsion Laboratory) spoke on the subject of "Remote Sensing Tools to Quantify the Ocean Carbon Cycle." She stated that the deep ocean has the largest carbon pool, and then she addressed the question of why we care about the oceanic carbon cycle. The air/sea flux depends on pCO_2 between the atmosphere and the ocean and also on the exchange coefficient E (usually a function of wind speed). The pCO_2 of the ocean depends on temperature and photosynthesis rates. CO_2 outgasses in regions of upwelling or warming while strong sinks go with downwelling and cooling.

The real interest is in *new* production. Oceanic primary productivity is fueled by nutrients outside the illuminated upper layer.

Carr has used satellite altimetry to decompose sea surface height (SSH) into various components such as Kelvin waves and Rossby waves. She has made the conversion from heat storage (HS) to nitrogen storage (NS) and finds that changes in HS are inversely related to changes in storage of total inorganic nitrogen (TIN). She has found the global new production to be 12 Gt of carbon.

Carr has found that the TOPEX/Poseidon nutrient-storage method is completely independent of chlorophyll concentration, primary productivity, or f-ratio measurements.

The final presentation of this IWG session was given by **Dave Glover** (Woods Hole Oceanographic Institution). Glover's subject was "Studying the Annual and Interannual Variability in Ocean Color Using Satellite Data and a Global Marine Ecosystem Model." Glover has attempted to develop a model of "intermediate complexity" that will incorporate an ecosystem model into the NCAR climate system model. He has used SeaWiFs data for daily images to get annual average results for one year in the 1990s. Working with a "semivariogram" function, he has been able to establish the "nugget," the "sill," and the "range" of the chlorophyll data. He has found that the range is highest in the equatorial region.

Glover outlined the elements of his new model: There are two classes of phytoplankton; one class of zooplankton; iron is modeled explicitly; and there are two kinds of detritus (sink and nonsink). The model also has forcing from surface shortwave radiation and includes iron deposition.

(Continued on page 20)

NASA Developing Space-Based "Sensor Web" — An "Internet" For Earth Observing Satellites

— David E. Steitz (dsteitz@mail.hq.nasa.gov), NASA Headquarters, Washington, DC

NASA is taking the first steps toward Internet-like connectivity among its future Earth sensing satellites with the funding of 30 research proposals from industry, academia, government and NASA centers in Advanced Information System Technology.

Known as "Sensor Web," this is the first in a series of information technology research initiatives that will help NASA's Office of Earth Sciences solve the massive challenge of collecting, processing, routing and storing Earth science measurement data. Of the 117 proposals submitted, the 30 selected cover a variety of topics ranging from satellite on-board processing, data collection and analysis, information transmission and wireless networks, to satellite platform control.

"With the increasing number of Earth observing satellites planned over the next decade, information technology will be the key to collecting and distributing Earth science data and information products to the global science community," said Dr. Ghassem Asrar, Associate Administrator for Earth Sciences at NASA Headquarters, Washington, DC.

"The concept of integrating a constellation of Earth observing satellites into a cohesive network of measurement instruments is what we call the 'Sensor Web.' It is similar to the Internet in that scientists and other users will have access to any on-orbit sensors and be able to direct and control those sensors in the same manner as we access information on the Internet today," Asrar said. "This activity exemplifies our commitment as an Agency to the development of cutting-edge technologies to benefit our science community and the nation as a whole."

The Sensor Web concept also will take full advantage of the revolution occurring in information and telecommunications technologies for direct delivery of space-based Earth observations to the end-user at the cost of placing a long distance telephone call, according to Asrar.

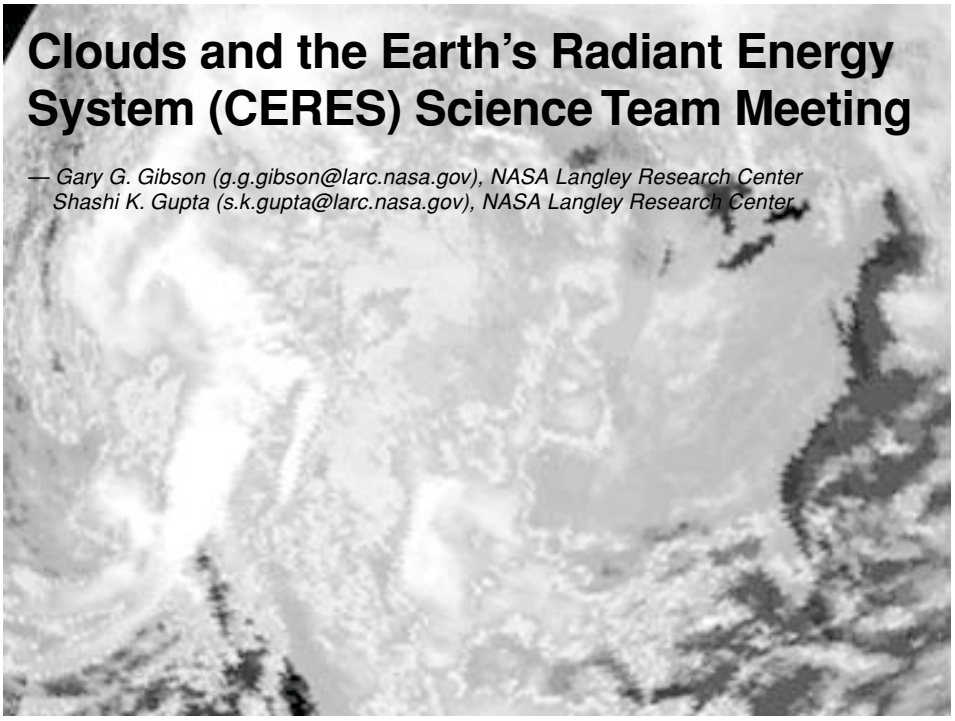
Research funded by this program will proceed over three years. During that period, a second increment of research projects will be initiated, focusing on other aspects of information technology essential to the next generation of Earth science missions. When fully implemented, an unprecedented amount of scientific data on the Earth's atmosphere, land and oceans will be available for study and public use.

NASA's Office of Earth Sciences is dedicated to the long-term study of how human-induced and natural changes affect our global environment.

The 30 research proposals selected by the Advanced Information System Technology program will have a total value of approximately $26 million over a three year period and will involve government, industry and university partners in 12 states and the District of Columbia. A description of the selected proposals can be found on the Internet at http://earth.nasa.gov/nra.

Clouds and the Earth's Radiant Energy System (CERES) Science Team Meeting

— Gary G. Gibson (g.g.gibson@larc.nasa.gov), NASA Langley Research Center
Shashi K. Gupta (s.k.gupta@larc.nasa.gov), NASA Langley Research Center



CERES Shortwave Radiation over North America. In this image, the dark and unreflective ocean is in black, while the more reflective land is grey to light grey. Clouds are very reflective, and can be seen standing out over the dark ocean.

The 20th Clouds and the Earth's Radiant Energy System (CERES) Science Team meeting was held at the Scripps Institution of Oceanography in La Jolla, CA on December 7-9, 1999. The CERES Science Team approved an improved version of the CERES ERBE-like (ERBE is the Earth Radiation Budget Experiment) data product from the Tropical Rainfall Measuring Mission (TRMM) to be released in January/February 2000. The team also approved a plan for release of the first combined cloud imager/radiation data product in April 2000. The next CERES Science Team meeting is scheduled for May 2-4, 2000 at the NASA Langley Research Center (LaRC).

Bruce Wielicki (LaRC), CERES Co-Principal Investigator, opened the meeting with an Earth Observing System (EOS) program status report. The Terra launch will be in December 1999, and the Aqua launch is scheduled for December 2000. CloudSat was selected for a launch in 2003 to fly in formation with Aqua.

CERES Instrument Status

Kory Priestley (LaRC) presented the instrument status report. The Terra spacecraft has been mated to the launch vehicle and is ready for a December launch. He discussed the activation timeline for CERES Terra instruments and indicated that the contamination covers will nominally be opened 30 days after launch. CERES instruments are ready for delivery to the Aqua spacecraft in early January. The CERES instrument on the TRMM spacecraft will be turned on when the CERES/Terra instruments are ready for intercalibration.

CERES ERBE-like Data and Validation

Richard Green (LaRC) showed day/night 3-channel results for Tropical Mean over oceans. His results indicate a likely source of error of either -0.4% in the shortwave (SW) channel or 0.4% in the total channel. Norman Loeb (Hampton University, HU) introduced a new CERES spectral correction algorithm which will be incorporated into all future CERES data processing. David Young (LaRC) presented validation results for the CERES ERBE-like product. He compared Tropical Means from CERES in 1998 with 5-year (1985-1989) averages from the Earth Radiation Budget Satellite (ERBS) scanner.

CERES Validation Experiments

Tom Charlock (LaRC) discussed progress in using Atmospheric Radiation Measurement (ARM) and Baseline Surface Radiation Network (BSRN) data for Surface and Atmospheric Radiation Budget (SARB) validation. The CERES ARM Validation Experiment (CAVE) now has surface data available on-line for over 30 sites. Don Cahoon (LaRC) briefed the team on two other validation initiatives, the CERES Oceanic Validation Experiment (COVE) and the CERES Fixed-wing Airborne Radiometer (C-FAR) system. The COVE is a fully operational BSRN site, and the C-FAR system is nearly ready to begin spectral and broadband albedo measurement flights.

Cloud Validation for SSF

Patrick Minnis (LaRC) discussed algorithms under development for Single Satellite Footprint (SSF) cloud retrievals. He also reported on efforts to refine calibrations of the Visible Infrared Scanner (VIRS) on TRMM. He presented intercalibrations of the VIRS narrowband data with similar channels on the Geostationary Operational Environmental Satellite (GOES), Advanced Very High Resolution Radiometer (AVHRR), and Along Track Scanning Radiometer (ATSR)

as well as with broadband CERES and window channel data. He presented global monthly average and instantaneous VIRS-derived cloud properties for January-October 1998. The results showed surprisingly large water cloud particle sizes, potentially indicating a large number of drizzling boundary layer clouds over open ocean.

Angular Models and TOA Fluxes

Norman Loeb outlined the differences between CERES SSF and ES8 products. He defined three options for reporting top-of-atmosphere (TOA) fluxes on SSF Edition 1: 1) use the current CERES angular distribution models (ADMs) with a flux associated with each footprint, but with known systematic flux biases for overcast conditions; 2) do not include flux products in the SSF Edition 1, but rather wait until sufficient CERES data have been collected to develop a full set of ADMs and report fluxes on SSF Edition 2; and 3) use only the clear-sky ADMs and do not produce fluxes under cloudy conditions.

CERES Data Systems

Jim Kibler (LaRC) announced the availability of an improved view_hdf tool for use in CERES data validation. He noted several changes to the ERBE-like hierarchical data format (HDF) data products including revised Collection Guides and the availability of daily and monthly plots.

Invited Presentations

V. Ramanathan (Scripps Institution of Oceanography, SIO) showed early results obtained from the first field phase (February-March 1998) of the Indian Ocean Experiment (INDOEX). Early results on anthropogenic aerosol radiative forcing in the Indian Ocean showed larger aerosol absorption than expected. Ramanathan showed that during the February-March period, this region is under the influence of the northeast monsoons and is blanketed by a thick layer of mixed aerosols blown in from the Indian subcontinent and beyond. The aerosol optical depth (AOD) in this region was as high as 0.6 with attendant radiative forcing of absorbed SW radiation at the surface as large as 40-50 Wm^{-2}. Ramanathan suggested that such a large forcing of surface-absorbed SW radiation has important implications for the hydrological cycle.

James McGuire (NPOESS Integrated Program Office, [IPO]) highlighted the possibility that an uninterrupted record of Earth radiation budget (ERB) measurements will be available to the community through the 2005-2009 period. This period is after the expected useful life of CERES instruments on Aqua and before CERES starts ERB measurements on the NPOESS (National Polar-orbiting Operational Environmental Satellite System). The IPO is working on several missions for this period which could include a CERES instrument to bridge the gap between Aqua and the NPOESS.

Michael Folk (National Center for Supercomputing Applications) discussed techniques for efficient use of HDF for archiving CERES data. He noted the strengths of HDF and discussed practical tips on efficient structuring of HDF files. Folk indicated that CERES implementation of HDF has been very efficient.

Working Group Reports

Instrument Working Group: Robert B. Lee III (LaRC) led in discussions of CERES/TRMM instrument accuracy. Measurement accuracy and precision goals have been satisfied. Kory Priestley and the instrument analysis team discovered the source of the small (0.8%) inconsistency in the three CERES channels, and the improved analysis shows an unprecedented consistency of 0.2% or better. This improvement will be included in Edition 2 data.

Cloud Working Group: Patrick Minnis led discussions of cloud retrieval, archival, data dissemination, and validation issues. Several issues must be resolved before the first archiving of cloud retrievals in April 2000. The group will continue studying the potential use of ECMWF (European Center for Medium-range Weather Forecasts) data for the MOA (meteorology, ozone, and aerosols) database even though first results were not encouraging.

Ron Welch (University of Alabama-Huntsville, UA-H) described a new cloud classifier that utilizes VIRS data to distinguish between ice and water clouds during daytime and to classify smoke and dust over water. Shaimi Nasiri (University of Wisconsin) presented a study of the sensitivity of ice crystal habits to retrieval methods. Mike Friedman (Oregon State University, OSU) reported on pixel-scale retrievals of homogeneous water clouds. Bing Lin (HU) showed good agreement between liquid water path and cloud temperature retrievals from coincident VIRS and TRMM Microwave Imager data. Larry Stowe (NOAA) gave a progress report on aerosol retrievals. Xiquan Dong (University of Utah) compared AVHRR-derived cloud temperatures and heights to surface-based lidar and radar retrievals of cloud properties during the Arctic Cloud Experiment.

Surface and Atmospheric Radiation Budget (SARB) Working Group: The meeting was led by Tom Charlock (LaRC). William Conant (SIO) presented results from the measurements of aerosol forcing of photosynthetically active radiation over the ocean obtained during INDOEX.

Radiative transfer model calculations and measurements agreed to within 5 Wm^{-2}. Mean aerosol radiative forcing (ARF) at the surface was about 8 Wm^{-2}. Fred Rose (Analytical Services and Materials, AS&M) reported on recent improvements to the Fu-Liou radiative transfer code, which is the basis of the SARB processing system. The changes considerably improved model performance; however, model-derived diffuse fluxes generally remained higher than the corresponding measured values.

Shashi Gupta (AS&M) showed validation results for the CERES surface-only flux algorithms. William Collins (National Center for Atmospheric Research, NCAR) presented results of a model study of ARF over the INDOEX region. Satellite-derived aerosol optical depths were assimilated by a chemical transport model and the NCAR column radiation model was used to derive TOA and surface ARF. Man-Li Wu (GSFC Data Assimilation Office, DAO) presented results of the latest changes to the data assimilation model at the DAO. Martial Haeffelin (Virginia Tech) showed new methods of instrument modeling to improve surface-based measurements of surface solar fluxes. His improvements eliminate spurious thermal signals (5-to-15 Wm^{-2}) in the solar data and probably explain at least part of the anomalous absorption.

ADM Working Group: Norman Loeb led the meeting with a general overview of critical ADM/inversion research issues. Steven Dewitte (Royal Meteorological Institute of Belgium) presented the algorithms to be used for scene identification in the Geostationary Earth Radiation Budget (GERB) experiment. Yong Hu (LaRC) discussed a stochastic radiative transfer model and a Monte Carlo model for ADM-related broadband radiative transfer calculations.

Norman Loeb presented LW and window channel ADMs for overcast conditions from CERES rotating azimuth plane scanner data. The overcast ADMs were stratified by precipitable water, surface temperature-cloud top temperature difference, and infrared (IR) cloud emissivity. Stratifying the ADMs by these parameters implicitly separates clouds of different phases. Loeb also presented results from a theoretical study examining how scene identification errors are reduced when ADM scene types are defined using percentiles of the cloud retrievals (e.g., cloud fraction, cloud optical depth) rather than the absolute retrieval values.

Time Interpolation and Spatial Averaging (TISA) Working Group: David Young led discussions of software development, narrowband-broadband correlations, the diurnal cycle, sampling errors, and validation. Near-term goals include evaluating data products for archival decisions, initial production of clouds for the gridded geostationary data set, validating the new directional models, and performing the first Terra/TRMM comparisons.

Kay Costulis (LaRC) reported that the 8 months of TRMM data have been processed through the major TISA subsystems. Yong Hu showed two methods for deriving broadband results from narrowband data sets and concluded that it is not possible to accurately compute broadband fluxes from only a few narrowband channels. Stephanie Weckmann (Virginia Tech) presented a new method for deriving albedo directional models for CERES using ERBE broadband TOA data. Jesse Kenyon (AS&M) continued studies of CERES spatial sampling errors. Mamoudou Ba (University of Maryland) showed results of recent studies of the diurnal cycle of outgoing LW.

Investigator Presentation Highlights

Bryan Baum (LaRC) presented results on characterization of cirrus clouds on a global scale. Cirrus radiative transfer model studies showed that visible/near-IR retrieval techniques are sensitive to ice crystal shapes, surface roughness, and vertical inhomogeneities.

Robert Cess (State University of New York at Stony Brook) presented results of a study on the impact of El Niño on cloud radiative forcing (CRF) over the warm pool region. The study was based on comparisons between 5 years (1985-1989) of ERBE data and 1998 CERES data, both sets averaged over 8 months from January to August. The ERBE data showed that SWCRF and LWCRF nearly cancelled each other over the Tropics, even for the 1987 El Niño period. Studies showed that this near cancellation was governed by the tropical tropopause temperature. Cess showed that during the El Niño year of 1998, the SWCRF/LWCRF ratio ranged from -1.3 to –1.4 and was not related to the tropopause temperature. He hypothesized that the increased magnitude of the ratio was a result of a preponderance of low clouds during 1998, which has a negligible effect on the SWCRF but lowers the LWCRF considerably.

Jim Coakley (OSU) presented satellite-derived AOD and ARF obtained during INDOEX (February-March 1999). Using calibrated AVHRR radiances, a dense aerosol was observed in the surface-to-3-km layer off the coast of the Indian subcontinent. Comparison of satellite-derived optical depth (up to 0.6) with surface-based photometer observations showed satellite values to be slightly higher. ARF efficiency derived from AVHRR radiances at 0.63 µm was found to be 40-45 Wm^{-2} per unit optical depth on a diurnal average basis. This was consider-

ably higher than the values derived at 0.55 µm from surface observations.

Steven DeWitte reported on the progress of the GERB processing system. The GERB instrument will be launched on the METEOSAT Second Generation (MSG) platform in October 2000 to provide accurate TOA radiative fluxes at high temporal resolution on a near real-time basis. The Spinning Enhanced Visible and Infrared Imager (SEVIRI) imager on the MSG platform will be used to determine cloud cover, cloud optical depth, and cloud phase. GERB will use CERES ADMs, and a CERES-compatible scene-identification algorithm and cloud-processing system.

Laura Fowler of Colorado State University (representing David Randall) reported on the progress in incorporating a new Fu-Liou-based radiative transfer model into the CSU General Circulation Model. The new model splits the SW region into 6 bands, the LW spectrum into 12 bands, and uses anomalous diffraction theory for ice-cloud optical properties.

Qingyuan Han of UA-H (representing Ron Welch) discussed the effect of particle size distribution on the retrieved optical properties of ice clouds. He explored the relationships of effective radius and effective variance with single scattering albedo and phase function.

Anand Inamdar of SIO (representing V. Ramanathan) presented results from a study of the water vapor greenhouse effect, using CERES total and window channel measurements. He analyzed regional and seasonal variabilities of the atmospheric greenhouse effect (G_a) derived from TOA CERES data and INDOEX surface data. The G_a in the non-window region is sensitive to upper tropospheric humidity (UTH). Based on a comparison of ERBE data for 1987 and CERES data for 1998, the clear-sky G_a is highly correlated with sea surface temperature (SST). Eric Wilcox (SIO) compared the effects of latent heat release and cloud radiative forcing on thermodynamic forcing of the atmosphere by clouds.

Martin Koehler of the Geophysical Fluid Dynamics Laboratory (representing Leo Donner) presented results of a study of the lifecycles of high cirrus clouds. He showed that studies relating to the lifetime of high clouds, their spatial evolution and decay, and their relationship with UTH can be conducted by tracking high clouds from GOES IR imagery.

Norman Loeb estimated TOA clear-sky broadband radiative flux and direct aerosol radiative forcing from satellite measurements. Aerosol radiative forcing was determined by two methods: 1) comparing cloud-free fluxes from CERES with model calculations (no aerosols); and 2) comparing fluxes from a radiative transfer model using VIRS aerosol optical properties with corresponding flux calculations with no aerosols. Loeb suggested that the largest uncertanties in aerosol radiative forcing are likely due to cloud contamination.

David Rutan (representing Richard Green) presented results of a comparison of TOA SW and LW fluxes derived from CERES data and corresponding fluxes from the ERBS wide field of view (WFOV) instrument. Nighttime LW comparisons showed smaller differences than for daytime. Comparison of reflected SW fluxes show a small bias but a large rms difference. The results are similar to previous comparisons of the ERBS scanner and WFOV instruments.

Lou Smith (Virginia Tech) reported on the development of a numerical filter technique for eliminating a slow mode transient in the instrument response. This transient arises because the disc on which the detector is mounted takes up some of the heat generated in the detector, and thus slows down its response to the incident radiation. Smith's numerical filter is being incorporated into the CERES processing system.

Larry Stowe presented early results from a computer-based processing system developed for the validation of AOD retrieved from CERES/SSF (VIRS) data. The processing system extracts satellite data over ground stations having sun photometer observations and produces validation data sets matched in space and time.

Michel Viollier of Laboratoire de Météorologie Dynamique, France, (representing Robert Kandel) presented radiation budget results obtained from the Scanner for Radiation Budget (ScaRaB) instrument, which provided data from November 1998 to March 1999. ScaRaB used data reduction procedures very similar to those for ERBE.

Bruce Wielicki summarized the large changes in Tropical Mean (20° N to 20° S) fluxes from ERBE to CERES that are not seen in model simulations. His results also indicated changes in tropical high-altitude cloudiness. CERES data showed a drop in reflected solar radiation and an increase in outgoing LW flux from the late 1980s to the late 1990s. The individual components of radiation change much more dramatically than net radiation. So, for climate change detection, component signals can be much larger in coupled ocean/atmosphere models.

Shi-Keng Yang of NOAA/National Centers for Environmental Prediction (NCEP) (representing Jim Miller) reported on ERB trends based on the first 40 years

(1949-1988) of NCEP/NCAR reanalysis. The SW CRF, averaged over the globe and over the tropics (30° N-30° S) both showed a slight (about 4 Wm^{-2}) uptrend over the period. The corresponding LW CRF showed a downtrend of about the same magnitude. All-sky and clear-sky outgoing LW showed small increases. Surface temperature and cloud amounts in the low, middle, and high layers showed no trends. Cloud-top temperatures showed an abrupt increase starting in 1957, coinciding with observation system changes initiated during the International Geophysical Year.

David Young (LaRC) compared cloud particle sizes derived from the VIRS 3.7-µm and 1.6-µm channels. The goal of this study was to develop algorithms for deriving cloud microphysical retrievals using the 1.6-µm channel to incorporate into the CERES cloud algorithm. Significant differences between the 1.6-µm and 3.7-µm retrievals can be used to infer additional information such as the presence of smoke over low clouds. A byproduct of this study was the determination that radiances from the VIRS 1.6-µm channel are 15-20% lower than those measured by the ATSR and MODIS (Moderate Resolution Imaging Spectroradiometer) Airborne Simulator (MAS) instruments.

CERES Education and Outreach

David Young reported for Lin Chambers (LaRC) on progress in the Students' Cloud Observations On Line (S'COOL) project, which is a part of the Outreach and Education Program at NASA/LaRC. Currently, 397 schools in 32 countries are involved in S'COOL activities, and over 2500 observations have been received from participating students. The S'COOL

(Continued on page 19)

Earth Science Enterprise (ESE) Data Pricing Policy to be Implemented within Earth Observing System Data and Information System (EOSDIS)

— Martha Maiden (mmaiden@hq.nasa.gov), Code YS, NASA Headquarters, Washington, DC

The ESE has decided to proceed with implementing a cost for distribution of products at the level of recovering the full marginal cost, consistent with OMB Circular A-130. By instituting a marginal cost charging policy, ESE is creating a means of remaining responsive to new and real increasing demand without incurring further burden on the U.S. taxpayer. NASA has officially submitted language for our 2001 authorization bill to enable us to retain receipts from recovering user charges.

This interpretation of our OMB guidelines and ESE Data Policy is consistent with changes in Enterprise direction over the last several years. The Earth Science Enterprise has broadened its mandate beyond our scientific goal of examining and modeling the Earth system to answer scientific questions of great societal importance, to include a stated goal of expanding and accelerating realization of national economic and societal benefits from Earth science, technology & information. This goal reemphasizes the importance of broad, and broadening, dissemination of our ESE remote-sensing data.

To this end, Dr. Ghassem Asrar created the Applications, Commercialization, and Education (ACE) Division. ACE is pursuing many strategies to ensure that secondary and tertiary providers with the "domain" expertise have pathways to make data readily available in a useful format to those end-user communities. The Earth Science Information Partners (ESIPs), the Regional Application Centers (RACs), and the Regional Earth Science Application Centers (RESACs) represent a few examples of the growing list of providers of ESE data, many of whom will be obtaining input data streams from EOSDIS.

So EOSDIS, in addition to providing data to the broad community of science users, will now be increasingly tasked to provide basic ESE data to the value-added data providers if our program is successful. ESIPs and RESACs, state and local government users, and commercial value-added providers are expected to represent a sizable part of the EOSDIS user profile.

While this legislation language has gone to Capitol Hill, it hasn't become law yet. Charging for data will not begin until it becomes law. In the meantime, billing and accounting policies and procedures will be developed with the help of the EOS community. ESE will work with all segments of our community as this charging policy is instituted to ensure that checks and balances are maintained and a smooth transition is made to this policy. In particular, for NASA-funded investigations, distribution costs already programmed within EOSDIS will be utilized.

Scientific Data Purchase Project: Background Information and Current Status

— Fritz Policelli (Fritz.Policelli@ssc.nasa.gov), NASA Scientific Data Purchase Project Manager, Stennis Space Center

Status Summary

The Scientific Data Purchase Project (SDP) contracts are currently in the second year of their 3-year contracts, which were initiated in September 1998. EarthSat has completed the Middle East, Africa, North America, and Central America in progress of providing global coverage of orthorectified Landsat products. The EarthWatch/Intermap team has delivered 40,000 sq km of CONUS DEM and ORI products (with the exception of an acquisition in Minnesota that is scheduled for May 2000), 40,000 sq km for Central America in support of NASA's MOU with the Central American Commission on Environment and Development (CCAD), and 13,000 sq km of Java, Indonesia products. Positive Systems is nearly fully tasked for its products at locations distributed across the United States. Tasking of the Space Imaging IKONOS satellite is advancing at a significant rate since the system was declared operational in January 2000. AstroVision is looking forward to launching the AVSAT in 2001. Up-to-date information, tasking, and coverage maps for all data products are accessible via the Internet at www.crsp.ssc.nasa.gov/databuy.

There are over 50 NASA affiliated science teams that are benefiting from the SDP; including the Vegetation Canopy Lidar and SRTM teams. The SDP data products are augmenting data products from the MODIS and Landsat sensors. The SDP is contributing to the science of the five science themes and to the NASA Regional Earth Science Application Centers (RESACs), Affiliated Research Centers (ARCs), Earth Observation Commercial Application Projects (EOCAPs), Earth Science Information Partnerships (ESIPs), Earth Science System Pathfinders (ESSPs), Shuttle Radar Topography Mission (SRTM), and Terra programs.

All products are available to all NASA affiliated scientists, regardless of the science team that requested the data. Many of the data sets are being used by a number of science teams for different science applications.

Background

The Office of Management and Budget allocated $50 M in FY 97 to the NASA ESE to conduct an experiment in purchasing remote-sensing data and data products from the private sector. The premise of the experiment was that new commercial remote-sensing solutions could provide NASA with quality data for the science community. The objectives of the experiment are to:

1. Explore commercial sector willingness to accept up-front financial risk to provide data to the government.
2. Determine if the commercial sector can deliver data products as "commodities" on schedule and within specification.
3. Determine the value of commercial data to on-going science within the NASA ESE Science Themes.

In September 1998, five contracts were placed for the second phase of NASA's purchase of Earth science data products. NASA ESE leadership has been very supportive of the Science Data Purchase concept.

"We are very pleased that the products we have chosen will provide NASA with valuable scientific data for our Earth sciences efforts," said Dr. Ghassem Asrar, Associate Administrator for NASA's Office of Earth Science, Washington, DC. "This purchase continues the multifaceted process of NASA working more aggressively with industry and other non-governmental organizations to advance scientific understanding of our Earth as a total environmental system."

The U.S. Congress approved the plan to initiate the data purchase activity in the fiscal 1997 NASA budget. The program is managed by the NASA Commercial Remote Sensing Program at Stennis Space Center, MS, the agency's lead center for fostering commercial applications of NASA Earth science data and related technology.

The SDP products are being used by research teams within NASA's Earth Science Enterprise, supporting the agency's portion of an internationally coordinated research effort to study the Earth's land, oceans, atmosphere, ice, and life as a global environmental system. NASA's Scientific Data Purchase Project is a model for reducing cost of providing data to research programs.

"By purchasing data upon delivery from the private sector instead of developing, building, and launching new satellites, NASA may be able to conduct and expand its scientific investigations at a much lower cost, while encouraging the growth of this economic area," Asrar said.

Products were selected based on several criteria, including "best science value" to the government, and the degree to which the offered data met the business and performance characteristics of the solicitation, including scientific utility and data rights.

Overview

Companies shown in the table below were selected for the data purchase:

Further Opportunities through Solicitations

NASA has established a policy to invite respondents to all NASA solicitations to include requests (including budget requests) for remote-sensing data and data products from the private sector in their proposals. NASA will purchase data from private sector sources, rather than build new satellites, when these data sources meet ESE science requirements and are cost-effective (Pace *et al.*, 1999).

Acquisition, Availability, and Science Networks of SDP Data

Data products from the EarthWatch/Intermap team, Positive Systems, Space Imaging, and EarthSat that have been acquired are available through requests on-line at www.crsp.ssc.nasa.gov/databuy. Data products delivered in the future from these vendors, and from AstroVision will continue to be available through the Commercial Remote Sensing Program and are expected to be delivered to the EROS Data Center for long-term archiving and distribution. All data products delivered to the Scientific Data Purchase Project have requirements for metadata compliant with the ECS standard for EOSDIS.

Details on data specifications, performance, verification, geographic locations, and applications will be topics of future articles.

Products	Companies	Product Coverage
GeoCover (orthorectified Landsat global data set)	Earth Satellite Corporation	Global
STAR-3*i* IFSAR (3 m DEM & 2.5 m ORI)	EarthWatch Inc. (with subcontract to Intermap)	CONUS: 40,000 sq km Central America: 40,000 sq km Indonesia: 13,000 sq km
ADAR 5500 (1 meter multispectral frame imagery)	Positive Systems, Inc.	Frame: 10,000 sq km Mosaic: 2,800 sq km
IKONOS (Original, Master, Model 1-m imagery & DEM)	Space Imaging Inc.	Original: 72,000 sq km Master: 23,000 sq km Model: 70 scenes (11 km x 11 km)
AVSAT (hi-res geostationary imagery)	AstroVision, Inc.	Western Hemisphere (5 months) Point and Dwell (40 events)

Verification and Validation

Approach

Each product is checked by the CRSP V&V team upon delivery from the vendor to verify that the product meets the geographic and performance specifications provided in the tasking request. The metadata are checked along with review of the "quick look" products to ensure that the products are suitable to approve payment to the vendor. The vendors are only paid after the products have been verified.

Results

To date, the CRSP team has found minor discrepancies with the delivered products, many of which were contained in the metadata associated with the products. Upon conveying these discrepancies to the vendors, NASA has found them to be very responsive in correcting the data (or associated metadata) and resubmitting in a timely fashion.

Access to SDP Data

Tasking

Tasking for the STAR-3*i*, ADAR 5500, and IKONOS data products can be accomplished by registering through the Tasking Request Web Site at www.crsp.ssc.nasa.gov/databuy. Tasking is not required for the GeoCover™ product. Tasking will be possible for the 40 event monitoring opportunities with the AVSAT once it is launched.

The SDP Task Review Committee at NASA HQ is led by Dr. Robert Schiffer and conducts reviews on a quarterly basis. Once task requests are approved, the vendor contracts are modified to provide authorization to acquire the approved data products.

Requests for Acquired Data

Any NASA-affiliated scientist may register with the SDP web site and request any product out of the available SDP data sets, independent of who submitted the task request.

Data Rights and Licensing

In general, the data rights are governed by the end user license agreements (EULA) that NASA negotiated with each vendor. These EULAs are available for review on the SDP web site. Each of the license agreements allows for use of the data by NASA-affiliated researchers.

Reference:

Pace, Scott, Sponberg, Brant, Macauley, Molly, *Data Policy Issues and Barriers to Using Commercial Resources for Mission to Planet Earth*, DB-247-NASA/OSTP, Rand 1999.

(Continued from page 16)

Clouds and the Earth's Radiant Energy System (CERES) Science Team Meeting

education outreach program recently won the NASA HQ Office of Earth Science Award for "Outstanding Earth Science Education Product."

Free Training Offered by NASA's Earth Science Data and Information System

NASA's Earth Science Data and Information System Project is sponsoring free training on the use of tools to search and order EOS and related data held in the EOSDIS archives, and to visualize and manipulate HDF-EOS data. This includes data collected from the Terra satellite. Instruments on Terra include ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer), CERES (Clouds and the Earth's Radiant Energy System), MISR (Multi-Angle Imaging Spectroradiometer), MODIS (Moderate Resolution Imaging Spectroradiometer), and MOPITT (Measurements of Pollution in the Troposphere).

This training is open to all interested scientists, data managers, data processing specialists, programmers, and others.

Two identical all-day sessions will be held at the GSFC Building 1 Training Center. Session 1 is July 6th and Session 2 is July 7th. Each session begins at 8:00 a.m. and runs to 5:00 p.m.

Training will include:

- EOS Data Gateway (EDG) for search and order of data,
- HDF-EOS Tools for organizing, dumping, and some manipulation of data,
- Data Visualization Tools for HDF-EOS data including WebWinds and DIAL.

Space is limited due to the hands-on nature of most of the sessions so please sign up early. Questions about the training session should be directed to Robin Pfister. To register, please complete the following information and e-mail to Robin Pfister by June 30th.

Name:
Affiliation:
Address:
Phone:
Fax:
E-mail:
Reason for taking this class:
What you would like to get out of this class:

Robin Tomlinson Pfister, Lead IMS Engineer, ESDIS Project
e-mail: robin.pfister@gsfc.nasa.gov
Address: NASA Goddard Space Flight Center
Mail Code 423, Bldg 32, Rm E240D
Greenbelt Md 20771
Phone: (301) 614-5171
Fax: (301) 614-5267

Two Earth Scientists Receive the Presidential Early Career Awards for Scientists and Engineers (PECASE)

— Ming-Ying Wei (mwei@hq.nasa.gov), New Investigator Program Manager

Dr. Waleed Abdalati of the Goddard Space Flight Center and Dr. Gregory P. Asner of the University of Colorado were among the 60 young researchers who were recipients of the fourth annual Presidential Early Career Awards for Scientists and Engineers (PECASE). PECASE awards are the highest honor bestowed by the United States Government on young professionals at the outset of their independent research careers. Award ceremonies were held at NASA Headquarters and the White House on April 12, 2000. See URL: www.whitehouse.gov/WH/EOP/OSTP/html/00413_2.html for further details.

NASA was one of eight federal agencies participating in the PECASE program in 1999, sponsoring a total of five awardees. NASA does not issue a special announcement for this award. Through the office of Dr. Kathie Olsen, Chief Scientist, NASA selects its awardees based on exceptionally meritorious proposals supported through the regular grant process.

Dr. Abdalati was selected in recognition of the development and application of innovative remote-sensing techniques to perform glaciological research within NASA's Earth Science Enterprise. Using a variety of instrumentation developed by NASA, Dr. Abdalati is studying the mass balance of Greenland and the ice caps in the Canadian Archipelago, thus providing an additional piece of knowledge about the puzzle regarding the regional climate in the Arctic. Dr. Abdalati was nominated by Dr. Kim Partington, Manager of the Polar Research Program.

Dr. Asner was selected in recognition of his leadership in developing innovative approaches to analyzing remotely sensed data from multiple sensors and applying them to regional and global biogeochemistry. Currently Dr. Asner is assessing human impacts on regional carbon cycling, nutrient losses, and trace-gas emissions in agriculture systems of the Southwestern U.S. and Mexico. Dr. Asner was nominated by Dr. Diane Wickland, Manager of the Terrestrial Ecology Program.

Both Drs. Abdalati and Asner were selected to receive the New Investigator Program (NIP) in Earth Science awards in fiscal year 1999. The NIP awards were established in 1996 to encourage integrated environments for research and education for scientists and engineers at the early stage of their professional careers. The program is designed for investigators at academic institutions and non-profit organizations. NASA's Office of Earth Science places particular emphasis on the investigators' ability to promote and increase the use of Earth remote sensing through the proposed research and education projects. The NIP awardees must be U.S. citizens or permanent residents. They must be recent Ph.D. recipients, graduating on or after January 1 of the year that is no more than five years before the issuance date of the particular announcement, and must not be a current or former recipient of an NIP or PECASE award. The NIP awardees constitute a primary, but not the only, source of nominations by the Office of Earth Science for the PECASE award. If an NIP awardee is selected for the PECASE award, the duration for the combined honor is five years.

The NIP proposals are openly solicited approximately every one-and-a-half years. A NASA Research Announcement for the NIP has just been issued with a proposal due date of July 19, 2000. The full announcement, including eligibility, proposal requirements, etc., is available at http://www.earth.nasa.gov/nra/current/nra00oes04/

(Continued from page 11)

Minutes of the Sixteenth ESE/EOS Investigators Working Group (IWG) Meeting

He has found a pretty good match between the model ecosystem chlorophyll distribution and that observed with SeaWiFS. He has done a number of iron simulations.

He illustrated an area where silica or iron or nitrogen are limiting. The Ross Sea area is a location where iron is limiting. He finds that small phytoplankton have a lesser need for iron than do the larger phytoplankton.

In closing, Glover said that he has succeeded in developing a global ecosystem model that does a good job, in comparison with available time-series data. Silica is in the model because large diatoms use silica as an important nutrient. Finally, ice melt may contribute to iron stimulation.

This sixteenth IWG meeting adjourned at 12:00 noon on April 13, 2000.

The 2nd International Workshop on Multiangular Measurements and Models (IWMMM-2)

— *Michel M. Verstraete and Bernard Pinty, Space Applications Institute Joint Research Centre, TP 440, I-21020 Ispra (VA), Italy*

The Second International Workshop on Multiangular Measurements and Models was held at the Joint Research Centre (JRC, Ispra, Italy) on September 15-17, 1999. This international event was jointly sponsored by the European Network for the development of Advanced Models to interpret Optical Remote Sensing data over terrestrial environments (ENAMORS) supported by the European Commission DG-XII under the Fourth Framework Programme, the Space Applications Institute (SAI) of the European Commission DG-Joint Research Centre (JRC), the U.S. National Aeronautics and Space Administration (NASA), and the Commonwealth Scientific and Industrial Research Organization (CSIRO) of Australia. The meeting was attended by well over 100 scientists from Europe, the United States, Australia, Canada, China, and Japan. These participants were involved or interested in modeling the anisotropy of the radiation field, in multiangular measurements, or in the exploitation of these tools and data in their own applications.

This 3-day meeting addressed 3 main objectives: (1) to establish the state of the art in direct and inverse modeling techniques, including those proposed for the operational exploitation of existing (e.g., geostationary satellites and the POLDER instrument) or upcoming (e.g., Terra) platforms, (2) to review current and near-future multiangular air- and spaceborne missions, as well as the latest developments in field and laboratory instruments, and (3) to demonstrate the usefulness of quasi-simultaneous multiangular measurements, when exploited with appropriate models, through either an improved accuracy and reliability of the results or the generation of new geophysical products. The workshop was organized around six sessions, each featuring keynote papers, poster presentations, and plenary discussions. The World Wide Web site (www.enamors.org) of the ENAMORS project was used to provide information on the various aspects of the conference. It hosted the proceedings of the meeting, and will continue to provide information on ongoing activities such as the RAMI exercise described below.

Theme 1: Simulations, inversions, and model intercomparisons

Extensive research and development on the simulation of the anisotropy of land surfaces and the overlying atmosphere took place over the past decades. Modeling the Bidirectional Reflectance Factor (BRF) of terrestrial targets and the techniques of inversion of such models against multiangular data sets have progressed significantly, in part thanks to the stimulation provided by current or upcoming availability of space missions permitting the acquisition of multiangular data from space. These events greatly motivated the community during the last few years, especially in terms of operational applications to exploit data acquired in space. In fact, the concrete steps towards bridging the gap between theoretical studies and practical applications are one of the major achievements of the community during this period. Although geographically extensive and high-quality data sets are yet to come, there is substantial evidence that the availability of advanced models and inversion techniques are not the main limiting factors any more. Furthermore, it is now beyond doubt that multiangular data allow a much more reliable and accurate estimation of the BRF fields at the land surface and of the products derived from these quantities, since they provide a much more severe constraint on the inversion process, especially with regards to accounting for atmospheric processes. These developments, in turn, allowed the characterization of both the surface and the atmosphere at once.

The time had thus come to take stock of the progress made and to propose a clear perspective of the field to current and prospective users of existing and upcoming multiangular and multispectral measurements. While preparing this conference, it was thought appropriate and timely to initiate a long-term exercise of RAdiative Model Intercomparisons (RAMI) similar to those that have been done in meteorology, atmospheric radiation, land-surface processes, and many other fields of geophysics. The first set of results was presented at the conference and will be published in the refereed literature.

The RAMI initiative, originally conceived as a self-organized activity of the BRDF community, was (and continues to be)

instrumental in: (1) quantifying the similarities and differences between canopy radiation-transfer models, (2) identifying model discrepancies and diagnosing possible pathological behavior of some models under specific observational scenarios, and (3) benchmarking three-dimensional model simulations and verifying their coherency in well-defined homogeneous and heterogeneous target conditions. The results gathered so far permit assessing the state of the art in radiation-transfer models and quantifying the performance of the participating models. This on-going exercise illustrates the level of maturity of the BRF modeling community. RAMI may thus serve as a test-bed against which future model developments can be evaluated. This exercise will also foster the exchange of codes within the community and, perhaps, in the long run, the development of community-approved BRF tools and libraries. The extension of RAMI to include intercomparisons in inverse mode has been proposed and will be pursued.

Theme 2: Laboratory, field, and air- and space-borne measurements

The second theme of the conference addressed the latest technological developments and scientific strategies for the acquisition of improved multiangular data. Oral and poster presentations described a variety of laboratory, field, and air- and spaceborne sensors designed to provide this type of data. Visits were organized to the European Goniometer (EGO) and European Microwave Signature Laboratory (EMSL), and a variety of field instruments, notably the Field Goniometer System (FIGOS) of the University of Zurich, the Wide Angle Airborne Camera (WAAC) of the German Aerospace Centre-Berlin, and the Mobile Unit for Field Spectroscopic Measurements (MUFSPEM) of the Technical University of Munich were exhibited in working condition. Other field instruments were discussed but not exhibited, such as the PARABOLA. This latter instrument was originally developed at NASA GSFC. A version of that sensor is currently operational at NASA JPL.

The acquisition and exploitation of airborne data were discussed in the context of specific campaigns, for instance, to support the Earth Radiation Budget Experiment (ERBE) and Clouds and the Earth's Radiant Energy System (CERES), conducted at the Atmospheric Radiation Measurement (ARM) sites. Similarly, results from AirMISR campaigns demonstrated the potential of multiangular data over selected sites. One major advantage of these airborne data sets is permitting the evaluation of the performance of models and inversion procedures, and showing the actual usefulness of these data in concrete applications.

Presentations on new space instruments provided an intriguing glimpse of what the future may bring in this field. Three new concepts were discussed at length, namely Leonardo, a multi-platform system of small satellites flying in formation to observe the same target from different directions, from NASA Goddard Space Flight Center; Triana, a Sun-orbiting platform to be located at the Lagrange L-1 point so that it keeps observing the illuminated face of the Earth in NASA's Small Earth Probes program; and the Land Surface Processes and Interactions Mission, a proposed Earth Explorer hyperspectral and multidirectional polar-orbiting platform from the European Space Agency. Although these missions are expected to evolve in time, for instance, in the light of the Terra mission results, they already capitalize on a quasi-simultaneous multiangular data acquisition principle. The opportunity to acquire such data in the thermal domain is also expected to lead to significant improvements in our understanding of the critical climatic and ecological processes, and to allow new applications.

These various observational systems do provide complementary information and ultimately help, jointly, in the full interpretation of remote-sensing data. They will stimulate and motivate the modelers in their efforts to provide better tools and techniques of Earth Observation, and the joint efforts of the remote-sensing community to generate more-reliable and accurate products.

Theme 3: Multiangular applications

The third theme addressed in this meeting had to do with the demonstration of the practical usefulness of multiangular observations in remote sensing. Although those scientists working in this field have long been convinced of the necessity to acquire and analyze multiangular data to take full advantage of remote-sensing products (in the optical as well as in the thermal spectral domains), this community has not been sufficiently forceful or convincing to promote its findings among the providers of remote-sensing data (in terms of designing multiangular sensors earlier) or the users of such products (in terms of systematically addressing these issues as part of their processing).

Why does the exploitation of the anisotropy of the radiation fields remain confined to what may appear as a small group of purists, when the analysis of the spectral, spatial, or temporal variations in the signals seems so obvious? Elements of response include: (1) historical and technological developments (it is worth remembering that remote sensing is rooted in the visual interpretation of photographic images), (2) the unavailabil-

ity of simultaneous multi-angular measurements for decades during which detailed spectral and spatial measurements were acquired, (3) a lack of awareness, outside the inner circle of specialists, of the actual importance of anisotropic effects on the measurements, or the mistaken belief that these effects can be neglected, (4) the relatively larger complexity of the underlying theories, or (5) the lack, until a few years ago, of a wide panoply of tools, both models and inversion procedures, usable in practical applications.

Once an initial intellectual and material investment is granted, the benefits of exploiting this new dimension in signal variability unfold. A number of presentations described the state of the art in the use of multiangular data. These included, among others, the derivation of surface albedo and aerosol optical-thickness information from monospectral but multidirectional data acquired with a geostationary satellite, or the derivation of surface and atmospheric properties from multispectral and multidirectional sensors such as the POLDER and AirMISR instruments. The Multi-angle Imaging SpectroRadiometer (MISR) sensor, launched on NASA's Terra platform in December 1999, was described and the main algorithms that have been developed to analyze its data were outlined. The very significant technological improvements brought about by the new generation of space instruments, especially in terms of on-board calibration, very high signal-to-noise ratio, much better navigation, as well as higher spatial and spectral resolutions, will exacerbate the detrimental effects of anisotropy if they are not taken into account, but also offer new opportunities to exploit this source of variability in its own right.

Although the accumulation of monodirectional observations over a long period of time does allow a documentation of anisotropic effects, such an approach is impractical or impossible to implement for the routine analysis of remote-sensing data because of the varying atmospheric conditions as well as the intrinsic evolution of the surface over these periods. Hence, the necessity to acquire multidirectional data quasi-simultaneously has been amply demonstrated.

Through the various presentations made during the meeting, it became clear that the two main advantages to be derived from the analysis of multiangular data are: (1) products similar to those already available but of much higher accuracy and reliability, and (2) new products that cannot be derived in any other way, for instance, on the structure and heterogeneity of the surface targets. These findings, in turn, justify *a posteriori* the limited investments already made in this field and the need for further efforts to now take full advantage of these incipient theoretical and observational capabilities.

Workshop recommendations

The participants in the Workshop took stock of the art in the observation, simulation, and exploitation of the anisotropy of the radiation field in remote sensing. They shared a common interest and excitement at the prospect of new data acquisitions in space from the upcoming MISR and POLDER instruments as well as from new concepts currently under study, and agreed on the following recommendations:

- Very significant efforts have been made in the last decades on the simulation of radiation transfer at and near the land surface as well as in the atmosphere. A major effort of model intercomparison (RAMI) has been initiated and should be pursued, both as a mechanism for modelers to confront and improve their tools, and as a way to inform the user community on the relative performance of existing approaches. This community exercise should be expanded to include more-comprehensive cases as well as to encompass comparisons in inverse mode.

- Multiangular measurement campaigns with laboratory, field, and airborne instruments should be systematically promoted as part of all major experiments involving remote sensing, so as to better document the anisotropic properties of the various targets of interest. These detailed investigations will greatly help constrain further model developments and help in the re-interpretation of the vast stores of satellite remote-sensing data accumulated over the past decades.

- Just as the exploitation of spectral variations, spatial contrasts, and temporal changes in remote-sensing data have proved very useful in a wide range of applications, taking advantage of the anisotropy that is always present in these data will permit the generation of new and better products. Future operational systems of Earth Observation should implement the systematic acquisition of data at both improved spatial and spectral resolutions under multiple observation directions, because that is the only way to guarantee the full exploitation of these data, for instance, in terms of addressing atmospheric problems.

- The performance of current models and inversion procedures is such that

the analysis of remote-sensing data has become highly sensitive to the quality of the data. Multiple on-board radiometric and spectral calibration mechanisms, high-precision navigational tools, very high signal-to-noise ratios and other such measures of sensor performance can be fully exploited to generate the highly accurate products and reliable services that will be required by users in the near future. The high performance of future sensors allowed by technological advances should thus be maintained or reinforced.

- Major efforts should be made to better inform the general scientific community, the users of remote-sensing data, national and international Space Agencies, as well as the funding agencies, on the significant benefits that can be derived from multiangular data acquisition. A similar conclusion had been reached at the International Forum on BRDF (IFB) held in San Francisco on December 11-12, 1998. An initial step in this direction was taken by Diner *et al*. (1999) *Bulletin of the American Meteorological Society*, **80**, 2209-2228. This IWMMM-2 conference and the proceedings that are currently in preparation will constitute a natural extension and implementation of this recommendation.

Terra Spacecraft Open For Business

— David E. Steitz (dsteitz@mail.hq.nasa.gov), Headquarters, Washington, DC
— Allen Kenitzer (akenitze@pop100.gsfc.nasa.gov), Goddard Space Flight Center, Greenbelt, MD

After a picture-perfect launch into space last December, NASA's premier Earth Observing System Satellite, Terra, has completed on-orbit checkout and verification and is "open for business."

Terra, an international mission and part of NASA's Earth Science Enterprise, is opening a new window to the Earth and is providing daily information on the health of the planet. First images from the five instruments aboard Terra are being presented during a press briefing April 19 at NASA Headquarters, Washington, DC.

Terra is the first satellite to monitor daily — and on a global scale — how the Earth's atmosphere, lands, oceans, solar radiation and life influence each other. Terra's wide array of measurements will give a comprehensive evaluation of the Earth as a system and will establish a new basis for long-term monitoring of the Earth's climate changes.

"Terra is measuring and documenting the Earth's vital signs, many of them for the first time," said Dr. Yoram Kaufman, Terra Project Scientist at NASA's Goddard Space Flight Center, Greenbelt, MD. "Like our taking vital signs to check the state of our own health, these data will help us diagnose several key aspects of the Earth's health.

"The data will help us understand our planet, aid in our distinguishing between natural and human-induced changes, and show us how the Earth's climate affects the quality of our lives."

NASA scientists revealed several stunning images from individual Terra sensors of the North American continent shown in many different layers. Images included global surface temperatures and "spring greening." Other first images range from the Indian subcontinent — showing relationships among population concentrations, air pollution, and vegetation — to concentrations of carbon monoxide in the lower atmosphere.

"Terra data, along with other measurements from surface-based and aircraft instruments, provide much-needed inputs for Earth science models," Kaufman concluded. "This ultimately will enable scientists to more accurately predict future climate change."

Many scientists believe that to successfully build predictive computer models of complex Earth interactions they must clearly understand global climatic processes and parameters. The Terra team estimates that the scientific community will complete the first Earth-system models making full use of Terra data by 2005.

The Earth Observing System series spacecraft are the cornerstone of NASA's Earth Science Enterprise, a long-term coordinated research effort to study the Earth as a global system and the effects of natural and human-induced changes on the global environment. Terra will use its position in space to observe the Earth's continents, oceans, and atmosphere with unprecedented measurement accuracy and capability. This approach enables scientists to study the interactions among these three components of the Earth system, which determine the cycling of water and nutrients on Earth.

NASA plans to encourage widespread use of Terra information to allow citizens, businesses, and governments to make more informed decisions on national issues affecting every American — health and safety, economic well-being, and quality of life in communities across the Nation.

The Earth Science Enterprise goal is to expand knowledge of the Earth system from the unique vantage point of space. Earth Science Enterprise data, which will be distributed to researchers worldwide at the cost of reproduction, are critical to informed environmental decisions.

Radiometric Measurement Comparisons at NASA's Ames Research Center

— *James J. Butler (butler@ltpmail.gsfc.nasa.gov), EOS Calibration Scientist, NASA's Goddard Space Flight Center, Code 920.1, Greenbelt, MD 20771*

From August 31 through September 2, 1999, five transfer radiometers and an Analytical Spectral Devices (ASD) FieldSpec-FR™ radiometer participated in a radiometric measurement comparison at NASA's Ames Research Center. These radiometers made measurements from the blue through shortwave infrared wavelength regions on three sources of uniform radiance. These sources included the National Institute of Standards and Technology (NIST) Portable Radiance (NPR) source (Brown and Johnson 1999), an Ames Spectralon™ reflectance panel illuminated by an irradiance standard lamp, and the Ames 76 cm-diameter integrating sphere source.

Previous radiometric measurement comparisons on the 76 cm sphere using the Ames ASD and the NASA Goddard Space Flight Center 746 Integrating Sphere Irradiance Collector (ISIC) (Johnson *et al*. 1996) revealed up to 30% differences in the radiances measured by the two instruments. A primary goal of the August/September comparison was to understand this difference by validating the radiance scale assigned by Ames to the lamp/reflectance panel and its transfer to the 76 cm integrating sphere. In the process of validating the Ames radiance scale, the Ames measurement approaches were also examined.

Sources

The three radiometric sources measured during the comparison at Ames are briefly described below.

NPR

The NPR is a 30 cm-diameter Spectralon™ sphere with a 10 cm diameter aperture. The sphere is equipped with 4, internally baffled, 30 watt lamps located at 90-degree intervals around the aperture. Two monitor detectors are used in the sphere. These include a silicon photodiode equipped with a photopic filter and an indium gallium arsenide detector with a 20 nm bandpass filter centered at 1540 nm. The NPR was calibrated in the NIST Facility for Automated Spectral Irradiance and Radiance Calibrations (FASCAL) (Walker *et al*. 1987) prior to the comparison on July 31, 1999.

Ames Irradiance Lamp and Reflectance Panel

At Ames, the radiance scale is realized using a reflectance panel illuminated by a 1000 W irradiance standard lamp. The radiance from the lamp/panel setup is calculated from a knowledge of the 8°/hemispherical reflectance divided by π, the irradiance of the lamp, and the distance of the lamp to the panel.

Ames 76 cm Integrating Sphere

The Ames 76 cm-diameter integrating sphere source is a barium-sulfate-coated aluminum shell equipped with twelve, 45 W lamps. The sphere is fan cooled and is equipped with three monitor detectors filtered at 400, 700, and 1200 nm. The sphere is used in the pre- and post-deployment calibrations of the Moderate Resolution Imaging Spectroradiometer (MODIS) Airborne Simulator (MAS) (King *et al*. 1996) and the MODIS Advanced Spaceborne Thermal Emission and Reflection radiometer (ASTER) Airborne Simulator (MASTER) instruments. The MAS and MASTER instruments support the design, development, and test of MODIS and ASTER algorithms and, with careful calibration, can provide a vicarious calibration for those instruments.

The Ames sphere calibration methodology is based on the transfer of the radiance scale realized by the reflectance panel and lamp to their 76 cm-sphere source using an ASD FieldSpec™ radiometer.

The Radiometric Measurement Challenge

In calibrations of the MAS and MASTER aircraft instruments, the Ames 76 cm-sphere is typically operated in an upward emitting geometry. It was realized in advance of the measurement comparison that the vertical operation of the sphere would present a measurement challenge to those transfer radiometers constrained to operate in a horizontal-viewing mode. In an effort to address that problem, a mirror was calibrated in the NIST Spectral Tri-function Automated Reference Reflectometer (STARR) facility (Proctor and Barnes 1996) for s and p reflectance at 45-degrees incidence and -45-degrees reflectance from 400 to 2500 nm. At Ames this fold mirror was employed in measurements of the NPR and Ames 76 cm

sphere sources and enabled horizontally operating radiometers to measure the Ames 76 cm sphere source.

The orientations of the fold mirror in measurements of the NPR and the Ames 76 cm sphere were not identical. In the case of the NPR, the mirror was mounted on a tripod and preferentially polarized the output of the sphere in a vertical direction. In the case of the 76 cm sphere, the mirror was suspended above the sphere aperture and preferentially polarized the output of that sphere in a horizontal direction. This polarization rotation was an issue for those horizontally configured radiometers unable to be rotated. The polarization responses of the radiometers were not measured prior to the Ames measurement comparison. The participants agreed to measure the polarization response of their radiometers following the comparison. Therefore, preliminary measurement results reported at the comparison did not take into account the polarization responses of the radiometers. Likewise, the results reported in this article do not take into account polarization issues and should be considered preliminary.

The Radiometric Measurement Comparisons

In the early afternoon of August 31, comparison participants met at building N259 at Ames Research Center and unpacked and powered their equipment. The participants included: (1) NIST (Carol Johnson and Steve Brown), with the EOS Visible Transfer Radiometer (VXR) (Johnson *et al*. 1998) and the EOS ShortWave Infrared Transfer Radiometer (SWIXR) (Brown *et al*. 1998); (2) the University of Arizona (UA) (Stuart Biggar and Ed Zalewski), with the UA Visible/Near InfraRed transfer radiometer (UA VNIR) (Biggar and Slater 1993) and the UA ShortWave InfraRed transfer radiometer (UA SWIR) (Spyak *et al*. 2000; Spyak 2000); (3) NASA GSFC (John Cooper and Jim Butler), with the 746 ISIC; and (4) NASA Ames (Pavel Hajek), with the ASD FieldSpec™ radiometer. The VXR, UA VNIR, and UA SWIR are fixed-filter radiometers. The SWIXR and 746 ISIC are scanning spectroradio-meters, and the ASD FieldSpec™ unit is a spectrograph.

The radiometric calibration sources measured by the radiometers are presented in Table 1 for each day of the comparison.

The NPR was measured with all four, 30W lamps illuminated. The VXR, SWIXR, UA VNIR, and UA SWIR measured the NPR with and without the fold mirror, while the 746 ISIC and ASD measured this source without the fold mirror. In measurements with the fold mirror, the mirror was aligned 45° to the sphere aperture; and the radiometers measured the sphere's radiant output at a mirror reflectance angle of -45°. By measuring the calibrated NPR directly and indirectly off the fold mirror, the polarization and attenuation effects of the reflectance of the mirror on radiance measured by the radiometers was determined. Figure 1 shows the VXR measuring the NPR without the fold mirror, and figure 2 shows the UA SWIR radiometer measuring the NPR using the fold mirror.

The VXR, SWIXR, UA VNIR, and UA SWIR radiometers measured the radiance produced by irradiance standard lamp F494 illuminating a Spectralon™ reflectance panel. The radiometer measurements were compared to the radiance predicted by Ames from their knowledge

Table 1. Radiometric measurements and wavelength calibrations performed during the Ames comparison

	Radiometers					
Date	VXR	SWIXR	UA VNIR	UA SWIR	746 ISIC	ASD
Aug. 31 PM	NPR with and without mirror	NPR with and without mirror	NPR with and without mirror	NPR with and without mirror	76 cm sphere without mirror	NPR without mirror Lamp F494 + panel 76 cm sphere without mirror
Sept. 1 AM	Lamp F494 + panel	Lamp F494 + panel	Lamp F494 + panel	Lamp F494 + panel	Wavelength calibration source	Lamp F494 + panel
PM	Lamp F297 + panel 76 cm sphere with mirror	76 cm sphere with mirror	76 cm sphere with mirror	Lamp F297 + panel 76 cm sphere with mirror	NPR without mirror	Lamp F297 + panel 76 cm sphere without mirror
Sept. 2 AM	76 cm sphere with mirror	76 cm sphere with mirror	76 cm sphere with mirror	76 cm sphere with mirror	NPR without mirror	76 cm sphere without mirror
PM		Wavelength calibration	NPR without mirror			Wavelength calibration source Lamp F494 + panel 76 cm sphere without mirror

of the irradiance of the lamp and the 8°/hemispherical reflectance of the panel divided by π. Figure 3 shows the UA VNIR radiometer measuring the Ames lamp/panel setup. In order to check the accuracy of the lamp irradiance calibration data, the measurements were repeated by the VXR and UA SWIR radiometers using a second calibrated irradiance lamp, F297, provided by the University of Arizona.

The radiometers measured the Ames 76 cm sphere with 12, 9, 6, and 3 lamps illuminated. In order to measure this sphere, the 746 ISIC spectrometer was mounted on an optical table; and the table/spectrometer assembly was raised above the vertically emitting sphere using a small forklift. The 746 ISIC input integrating sphere was oriented downward to directly collect the upwelling irradiance from the 76 cm sphere. This is illustrated in Figure 4. The Ames ASD also directly measured the 76 cm sphere by using the ASD to transfer a radiance scale from the Ames irradiance lamp F494 and Spectralon panel to the 76 cm sphere. The VXR, SWIXR, UA VNIR, and UA SWIR radiometers measured the source using the fold mirror, which was suspended over the sphere aperture. The fold mirror was mounted on a graduated rotation stage. By positioning the radiometers around the 76 cm sphere, each radiometer measured the sphere in series simply by rotating the mirror to the appropriate angle. Figure 5 shows the radiometers positioned around the integrating sphere.

In addition to the radiometric sources, the SWIXR, 746 ISIC, and ASD performed wavelength calibrations using an atomic-line source provided by NIST. This source employed sets of various atomic line penlamps inserted into a 20 cm-diameter Spectralon™ integrating sphere.

Preliminary Results

NPR Radiance Measurements:

Table 2 presents preliminary results from the transfer radiometers and the Ames ASD measuring the NPR. Radiances are reported for radiometer bands with nearly the same center wavelengths.

When comparing each radiometer's measurement at each wavelength with the average at that wavelength, the radiometer measurements on the NPR agreed to better than ±3.1% at 412 nm, ±2.7% at 661 nm, ±1.7% at 870 nm, ±2.4% at 1646 nm, and ±3.0% at 2263 nm.

The VXR, UA VNIR, and 746 ISIC measured higher radiances than the Ames ASD at visible and near infrared wavelengths. The SWIXR, UA SWIR, and 746 ISIC also measured higher radiances than the Ames ASD at shortwave infrared wavelengths, with the UA SWIR showing the best agreement with the Ames ASD.

Figure 1. The NIST VXR measuring the NPR integrating sphere source at NASA Ames Research Center.

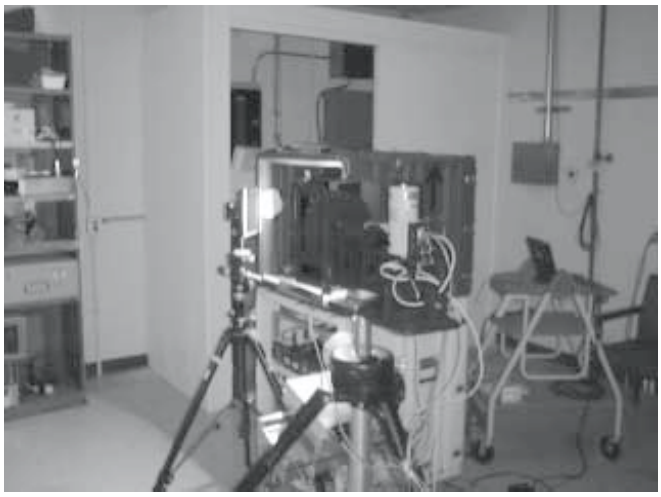


Figure 2. The UA SWIR radiometer measuring the NPR source using the fold mirror.

Figure 3. The UA VNIR radiometer measuring the Ames reflectance panel illuminated by a 1000 W FEL irradiance standard lamp. The radiometer is in the foreground with the white reflectance panel on the left and the bright lamp on the right.

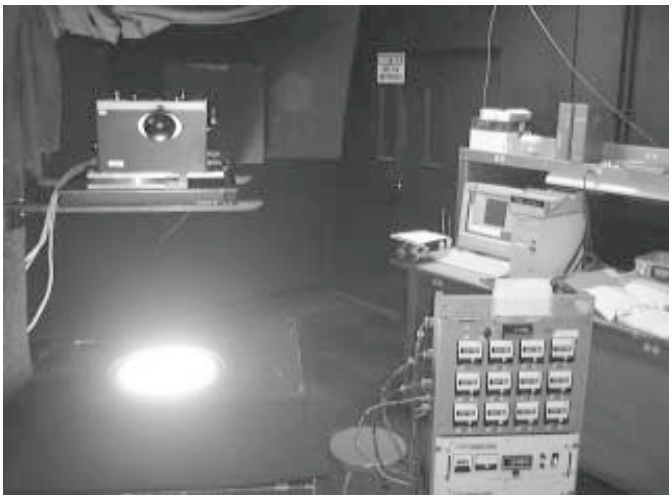


Figure 4. The 746 ISIC measuring the Ames 76 cm integrating sphere source. The 746 ISIC is cantilevered over the aperture port on the left. The sphere lamp timers and a single power supply are seen at the bottom right. On the lab bench is seen the computer used to acquire data from the sphere monitor detectors.

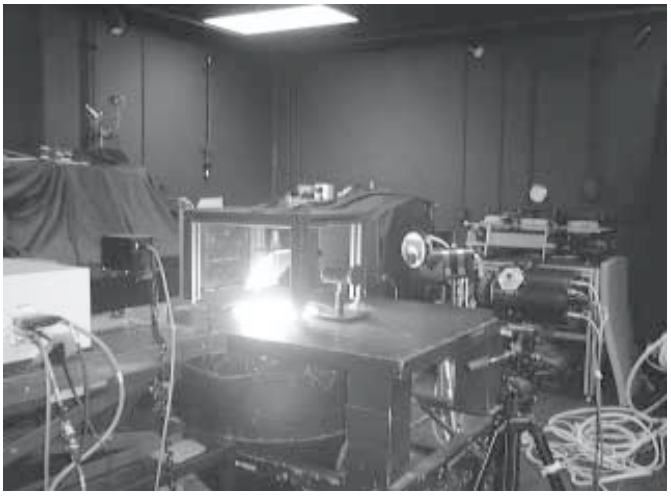


Figure 5. Four transfer radiometers positioned to measure the Ames 76 cm sphere. The fold mirror is located immediately above the sphere aperture and is mounted to a rotation stage. The NIST SWIXR radiometer is on the left. The NIST VXR is seen in the foreground on the right, followed by the UA VNIR and UA SWIR radiometers. In this photo, the VXR is measuring out-of-field contributions to its radiance measurement using a post-mounted, low-reflectance, black disk located in front of the fold mirror.

Figure 6 shows the % difference of the 746 ISIC and Ames ASD NPR measurements from the NPR calibration performed at the NIST FASCAL facility prior to the comparison. Measurements of the NPR by the VXR and SWIXR at NIST prior to the Ames comparison and during the comparison indicate that the NPR was stable to within 0.3% in the visible and near infrared and to within 0.5% in the shortwave infrared.

Table 2. Preliminary radiometric measurements on the NPR with 4-30 W lamps illuminated. Radiances are in units of Wm^{-2} sr^{-1} μm^{-1}. % difference of each radiometer measurement from the Ames ASD measurement are provided.

Radiometer	412 nm	661 nm	870 nm	1646 nm	2263 nm
VXR	118.5 (3.76%)	1066 (3.13%)	1529 (3.07%)	-	-
UA VNIR	118.5 (3.76%)	1060 (2.55%)	1485 (0.1%)	-	-
UA SWIR	-	-	-	738.2 (0.69%)	174.9 (0.29%)
SWIXR	-	-	-	765.9 (4.47%)	183.0 (4.33%)
746 ISIC	119.6 (4.73%)	1087.4 (5.20%)	1532.9 (3.33%)	755.2 (3.01%)	177.7 (1.31%)
Ames ASD	114.2	1033.6	1483.5	733.1	175.4

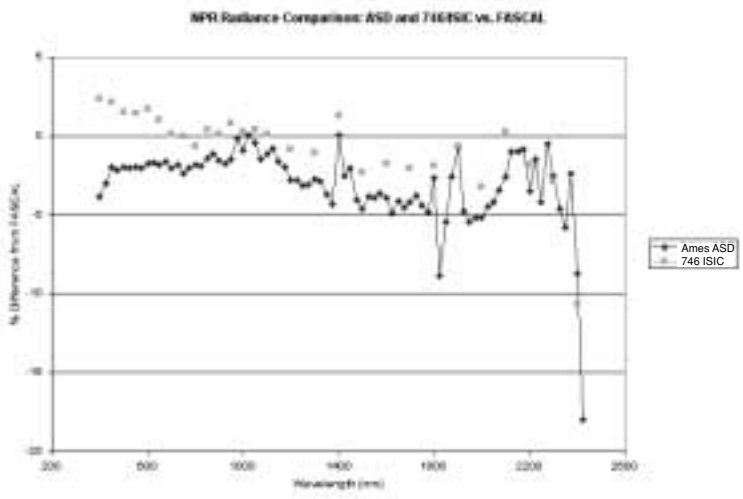


Figure 6. Percent difference of the NPR radiance as measured by the Ames ASD and the 746 ISIC from the July 31, 1999 FASCAL calibration. Ignoring water vapor absorption regions, the ASD and the 746/ISIC agree to better than 5% from the visible through shortwave infrared.

Ames Lamp/Reflectance Panel Measurements:

Table 3 presents preliminary results from the transfer radiometers measuring radiances obtained from the Ames lamp/reflectance panel. Also provided are the radiances predicted by Ames using calibrated lamp irradiance values and the 8°/hemispherical reflectance of the panel divided by π. Radiances are reported for radiometer bands with nearly the same center wavelengths.

When comparing the transfer radiometer measurements at each wavelength with the average at those wavelengths, the measurements of the VXR and UA VNIR on the lamp/reflectance panel agreed to better than ±0.5% at 412 nm, ±0.6% at 661 nm, ±0.06% at 870

nm, ±1.4% at 1646 nm, and ±1.5% at 2263 nm. The data of Table 3 indicate that the VXR and UA VNIR measured radiances which were 2.7 to 4.5% higher than those predicted by Ames. The SWIXR and UA SWIR measured shortwave infrared radiances from the lamp/reflectance panel were also higher than the predicted Ames measurements by 1.6 to 4.9%.

Table 3. Preliminary radiometric measurements on the Ames irradiance lamp F494/reflectance panel. Radiances are in units of $Wm^{-2}\ sr^{-1}\ \mu m^{-1}$. % difference of each radiometer measurement from the Ames calculated radiances are provided.

Radiometer	412 nm	661 nm	870 nm	1646 nm	2263 nm
VXR	1.842 (3.48%)	12.93 (2.7%)	17.82 (3.85%)	-	-
UA VNIR	1.86 (4.49%)	13.1 (4.05%)	17.8 (3.73%)	-	-
UA SWIR	-	-	-	85.39 (2.02%)	36.59 (1.64%)
SWIXR	-	-	-	87.77 (4.86%)	37.66 (4.61%)
Ames Predicted radiances	1.78	12.59	17.16	83.7	36

76 cm Sphere Measurements:

Table 4 presents preliminary results from the transfer radiometers and the Ames ASD measuring the Ames 76 cm sphere. Radiances are reported for radiometer bands with nearly the same center wavelengths.

Table 4. Preliminary radiometric measurements on the Ames 76 cm sphere with 9-45 W lamps illuminated. Radiances are in units of $Wm^{-2}\ sr^{-1}\ \mu m^{-1}$. % difference of each radiometer measurement from the Ames ASD measurement are provided.

Radiometer	412 nm	661 nm	870 nm	1646 nm	2263 nm
VXR	27.87 (5.97%)	275.8 (4.43%)	389.5 (5.96%)	-	-
UA VNIR	27.9 (6.08%)	274 (3.75%)	376 (2.28%)	-	-
UA SWIR	-	-	-	137.1 (1.48%)	35.86 (-0.95%)
SWIXR	-	-	-	141.9 (5.03%)	-
746 ISIC	28.1 (6.84%)	277.7 (5.15%)	381 (3.64%)	140.7 (4.14%)	36.9 (1.93%)
Ames ASD	26.3	264.1	367.6	135.1	36.2

When comparing the radiometers' measurements with the average measurement at each wavelength, the radiometer measurements on the 76 cm sphere agreed to better than ±4.7% at 412 nm, ±3.3% at 661 nm, ±3.0% at 870 nm, ±2.9% at 1646 nm, and ±1.6% at 2263 nm. At visible and near infrared wavelengths, the VXR, UA VNIR, and 746 ISIC measured radiances were higher than those measured by the Ames ASD by 2.28% to 6.84%. At shortwave infrared wavelengths, the SWIXR and 746 ISIC measured higher radiances than the ASD. The UA SWIR measured a slightly higher radiance than the ASD at 1646 nm and slightly lower radiance at 2263 nm.

Discussion

Preliminary radiance measurements in the visible, near infrared, and shortwave infrared from five transfer radiometers and the Ames ASD agreed to better than ±3.1% relative to the average when measuring the NPR and to better than ±4.7% relative to the average when measuring the Ames 76 cm sphere. For both sphere sources, the VXR, UA VNIR, and 746 ISIC measured radiances higher than the Ames ASD at visible and near infrared wavelengths. A significant part of this difference can be attributed to the Ames realization of their radiance scale using their lamp and reflectance panel. Preliminary visible and near infrared measurements on the lamp/reflectance panel by the VXR and UA VNIR were 2.7% to 4.5% higher than radiances predicted by Ames from a knowledge of the lamp's irradiance and the panel's 8°/hemispherical reflectance. Measurements by the UA SWIR and SWIXR on the Ames lamp/panel were 1.6% to 4.9% higher than the Ames predicted radiances.

Because the NPR was calibrated at NIST prior to the Ames comparison and was verified using the transfer radiometers to be stable to within 0.3 to 0.5%, the NPR is a NIST traceable calibration source which could be used to eliminate the source of unexplained bias in the Ames ASD measurements traceable to their lamp/panel measurements.

In addition to validating the Ames predicted lamp/reflectance panel radiance and the Ames calibration of their 76 cm sphere source, the measurement comparison produced a number of specific recommendations to improve the overall Ames measurement technique and to reduce measurement uncertainties. During measurements on the lamp/panel, several sources of error were identified. First, the distance from the irradiance lamp to the reflectance panel was determined to be 99.6 cm instead of the assumed 100.0 cm. Second, the opening

in the baffle between the lamp and the reflectance panel was slightly undersized, causing a vignetting of the irradiance from the lamp to the panel. Third, the ASD, when positioned to measure the reflectance panel, did not view the exact center of the panel. Fourth, values of 8°/hemispherical reflectance divided by π should not be used in lieu of actual measurements of the 0°/45° bidirectional reflectance distribution function (BRDF) for the reflectance panel. Fifth, the black cloth used around the lamp/reflectance panel setup to control stray light had low reflectance in the visible and near infrared but up to 38% reflectance in regions of the shortwave infrared. These factors contributed to an overall error in the realization of a radiance scale by Ames using their lamp/reflectance panel. This error was then propagated through their measurements on the NPR and 76 cm spheres. Prior to the comparison, monitor detectors were installed in the 76 cm sphere. These detectors were operated for the first time during the measurement comparison. At the time of the comparison, the monitor detector system was being tested; and the need for additional work on these system was identified to permit short and long-time monitoring of sphere stability and repeatability. Sphere stability and repeatability are two important issues in the use of the sphere for the pre- and post-deployment calibration of airborne validation instruments.

Conclusion

From August 31 to September 2, 1999, five transfer radiometers and the Ames ASD participated in a measurement comparison at Ames Research Center on three radiometric sources. Preliminary results indicated that the radiometers agreed to better than ±3.1% relative to the average when measuring the NPR sphere source and to better than ±4.7% relative to the average when measuring the Ames 76 cm sphere source. For both spheres, the Ames ASD measured radiances in the visible and shortwave infrared were 0.1% to 5.2% and 2.3% to 6.8% lower, respectively, than the transfer radiometer measured radiances. For these sources, the Ames ASD measured radiances in the shortwave infrared were 0.3% to 4.5% lower and 1.0% higher to 5.0% lower, respectively, than the transfer radiometer measured radiances. A significant fraction of the difference in the measurements of the ASD and the transfer radiometers was in the comparison of transfer radiometer measurements of the Ames lamp/reflectance panel to radiance predicted by Ames. The transfer radiometers indicated that the Ames prediction of lamp panel radiance was 2.7% to 4.5% too low in the visible and near infrared and 1.6% to 4.9% too low in the shortwave infrared.

Regarding the preliminary results presented in this article, the implementation of several improvements to the Ames measurement setup led to the good agreement of the Ames radiometer measurements with the transfer radiometer measurements. This claim is supported by the fact that the comparison was successful at understanding and diagnosing previous large differences between the ASD and 746 ISIC measurements. The data of figure 6 indicate that the radiance measurements by the ASD and the 746 ISIC agreed to better than 4.1% from 450 to 2400 nm.

Acknowledgement

The authors would like to thank Ted Early and Yvonne Barnes of the NIST Optical Technology Division for their timely measurements of polarized reflectance of the fold mirror in the NIST STARR facility.

References

Biggar, S.F. and P.N. Slater, 1993: Preflight Cross-calibration Radiometers for EOS AM-1 Platform Visible and Near-IR Sources. *Proc. SPIE* **1939**, 24.

Brown, S.W. and B.C. Johnson, 1999: A Portable Integrating Sphere Source for Radiometric Calibrations from the Visible to the Shortwave Infrared. *The Earth Observer* **11**, 14.

Brown, S.W., B.C. Johnson, and H.W. Yoon, 1998: Description of a Portable Spectroradiometer to Validate EOS Radiance Scales in the Shortwave Infrared. *The Earth Observer* **10**, 43.

King, M.D., W.P. Menzel, P.S. Grant, J.S. Myers, G.T. Arnold, S.E. Platnick, L.E. Gumley, S.C. Tsay, C.C. Moeller, M. Fitzgerald, K.S. Brown, and F.G. Osterwisch, 1996: Airborne Scanning Spectrometer for Remote Sensing of Cloud, Aerosol, Water Vapor, and Surface Properties. *J. Atmos. Oceanic Technol*. **13**, 772.

Johnson, B.C., J.B. Fowler, and C.L. Cromer, 1998: Volume 1. The SeaWiFS Transfer Radiometer (SXR). *SeaWiFS Postlaunch Technical Report Series*, NASA TM-1998-206892.

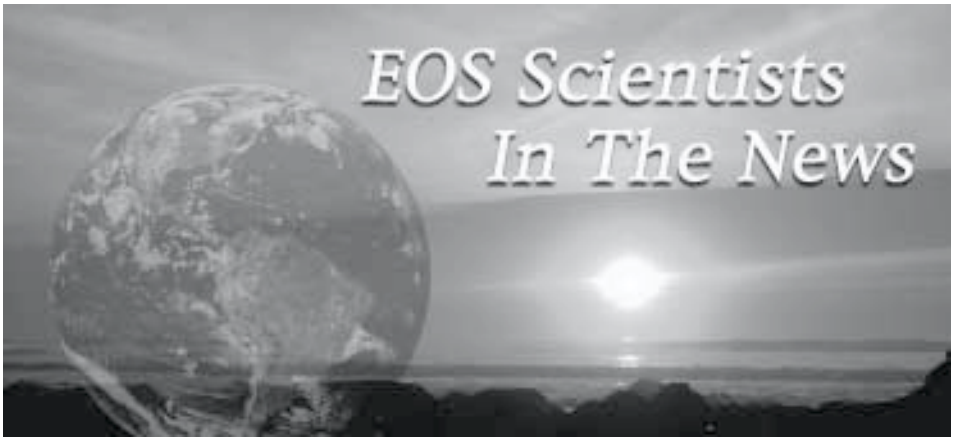
Johnson, B.C., S.S. Bruce, J.M. Houston, T.R. O'Brian, A. Thompson, S.B. Hooker, and J.L. Mueller, 1996: Volume 37. The Fourth SeaWiFS Intercalibration Round-robin Experiment (SIRREX-4). *SeaWiFS Technical Report Series*, NASA TM-104566.

Proctor, J.E. and P.Y. Barnes, 1996: NIST High Accuracy Reference Reflectometer-Spectrophotometer. *J. Res. Natl. Inst. Stand. Technol.*, **101**, 619.

Spyak, P., D. Smith, J. Thiry, and C. Burkhart, 2000: Shortwave-infrared Transfer Radiometer. Part 1. Design and Performance Predictions. submitted for publication in *Applied Optics*.

Spyak, P., 2000: Shortwave-infrared, Transfer Radiometer. Part 2. Characterization and Performance. submitted for publication in *Applied Optics*.

Walker, J.H., R.D. Saunders, and A.T. Hattenburg, 1987: Spectral Radiance Calibrations. *NBS Special Publication*, SP250-1, U.S. Government Printing Office, Washington, D.C.



"Global Warming Could Be Bad News For Arctic Ozone Layer," (April 6) *Nature* by Peter Aldhous. **Paul Newman** (NASA GSFC) reports that Arctic ozone loss is at alarming levels based on collaborative study between the European Commission's THESEO 2000 and NASA's SOLVE mission. Newman says that this year at altitudes of 18 kilometers, more than 60 percent of the ozone layer was destroyed.

"Monitoring Earth's Vital Signs," (April) *Scientific American* by **Michael King** (NASA GSFC) and David Herring (SSAI). They explain how NASA's Earth Observing System Terra satellite will use its five state-of-the-art instruments to monitor the Earth.

"Huge Berg, Warming Probably Not Linked," (March 27) *USA Today* by Jack Williams. **Ted Scambos** (Univ. of Colo.) says the iceberg that broke off Antarctica's Ross Ice Shelf on March 19 is not a result of global warming. Scambos says Antarctica has ice shelves that extend into the ocean and when they are forced to bend and flex with the tide they can crack, which could result in large pieces of ice breaking off.

"Globe's Missing Warming Found in the Ocean," (March 24) *Science* by Richard Kerr. **James Hansen** (NASA GISS) says that rising ocean temperatures have delayed surface warming, but this is temporary and by the end of the next century the world will be between 1.5 and 4.5 degrees Celsius warmer.

"Plants Seen As Unpredictable Carbon Sponge," (March 18) *Science News* by Janet Raloff. **David Schimel** (Max Planck Institute) found that the rate of carbon dioxide absorption by plants is unpredictable and can vary by 100 percent from one year to the next. Schimel says that land-use changes are an important factor in how plants soak up carbon dioxide.

"Wayward Winds May Warn of Storms," (March 17) *Associated Press* by Randolph Schmid. **Dennis Hartmann** (Univ. of Washington) has found that Caribbean and Gulf storms are four times more likely to occur when Pacific winds blow from the west rather than from the east.

"Pollution Keeps Rain Up in the Air," (March 11) *Science News* by Tina Hesman. **Daniel Rosenfeld** (Hebrew University of Jerusalem) using satellite data from NASA's Tropical Rainfall Measuring Mission has found that air pollution inhibits rainfall and snowfall. Rosenfeld's research was also featured on *National Public Radio*.

"Heat Rising From Cities Appears To Be Changing Regional Weather Patterns," (March 6) *San Francisco Gate* by Jim Doyle. **Dale Quattrochi** (NASA MSFC) discusses how cities are creating their own climate by paving more roads and planting fewer trees. Quattrochi says that large cities create "domes of heated air" between 3 and 12 degrees warmer than surrounding areas.

"Sprawling Over Croplands," (March 4) *Science News* by Janet Raloff. **Marc Imhoff** (NASA GSFC) found that in California 16 percent of the best farmland is under development. Imhoff says that urban sprawl is also a problem in China's Pearl River Delta where urban growth tripled between 1988-1996.

"Global Warming: The Contrarian View," (Feb. 29) *New York Times* by William K. Stevens. **John Christy** and **Roy Spencer** (NASA MSFC) found similarities when they compared surface temperature measurement trends with satellite data, but the satellites showed no warming in the atmosphere near the tropics.

EOS researchers:

Please send notices of recent media coverage in which you have been involved to:

Emilie Lorditch, EOS Project Science Office, Code 900, Goddard Space Flight Center, Greenbelt, MD 20771
Tel. (301) 441-4031; fax: (301) 441-2432; e-mail: elorditc@pop900.gsfc.nasa.gov

NASA Earth Science Enterprise Education Program Update

— *Managing Editor (Acting): Ming Ying Wei (mwei@hq.nasa.gov), Office of Earth Science, NASA Headquarters*

— *Editor and Writer: Theresa Schwerin (theresa_schwerin@strategies.org), Associate Director, Education, Institute for Global Environmental Strategies (IGES)*

This report is broadcast as a communication tool, bridging NASA Headquarters (HQ), NASA Research Centers, the Jet Propulsion Laboratory (JPL), and other NASA-supported institutions involved in NASA Earth Science Enterprise (ESE)-related research and education activities. For those who are interested in subscribing, please send e-mail to mtpe_ed_newsletter@listserv.gsfc.nasa.gov. Back issues of this report are available on the Web at: http://earth.nasa.gov/education/edreports/index.html.

Earth System Science Education (ESSE) Meeting To Be Held In June

The Universities Space Research Association (USRA) will hold the next ESSE meeting June 14-16, 2000, at the American Center for Physics facility near the University of Maryland, College Park. The ESSE meeting immediately follows the USRA/Goddard Space Flight Center Visiting Lecture Series to be held June 12 - 14.

Sponsored by NASA through USRA, ESSE supports the development of undergraduate curricula in Earth System Science and Global Change at 44 participating colleges and universities.

Topics to be covered at the ESSE meeting will include discussion of the future of the ESSE collaborative, opportunities to contribute resources to the developing Digital Library for Earth System Education (DLESE), the multi-agency Digital Earth initiative, the status and plans for the Journal of Earth System Science Education (JESSE), and plans for contributing to the NASA Triana Mission education and outreach activities. Emphasis will be placed on needs and opportunities to impact classroom education in Earth System Science through collaboration and use of the Internet and Digital Library for the creation and exchange of educational resources.

For more information about ESSE, see http://www.usra.edu/esse/essonline/aboutesse.html. This meeting will be the last formal ESSE community meeting under the current NASA grant. For more information, contact Martin Ruzek at ruzek@usra.edu or see http://www.usra.edu/esse/esse2000 for an updated meeting agenda.

New NPS Liaison At GSFC

Anita Davis is the new National Park Service's (NPS) liaison to NASA's Goddard Space Flight Center in Greenbelt, MD, where she will serve as the primary contact between the two agencies. Her goal is to develop new, and strengthen existing, communication links between the two agencies, in order to facilitate the transfer of information between NPS and NASA staffs. She will work with NASA's education, public affairs, visitor center and science staff, gleaning and disseminating useful information for NPS interpreters, managers, and scientists, and will participate in public outreach activities conducted by NASA and the NPS.

Ms. Davis has worked with NPS for over 10 years. Most of this time was spent at Grand Canyon National Park, where she worked for several years in interpretation, most recently as the liaison between the scientific community and interpretation. When her one-year detail at Goddard is completed, she will return to Sunset Crater Volcano, NM.

If you have information you feel might fit into this collaborative effort, or would like information about the park service, please feel free to contact Ms. Davis at (301) 286-0535 or via e-mail at Anita_Davis@nps.gov or adavis@pop100.gsfc.nasa.gov.

Upcoming Workshops, Meetings, And Opportunities

June 4-July 28
Undergraduate Research Internships In Earth System Science — The Center for Hydrology, Soil Climatology, and Remote Sensing's (HSCaRS) Undergraduate Summer Enrichment Program at Alabama A&M University in Huntsville, Alabama provides summer research opportunities for undergraduate minority and women students in Earth System Science. More details on the program can be found at http://space.hsv.usra.edu/SEP.html/Index.html.

June 5-August 11
Graduate Student Summer Program In Earth System Science, Goddard Space Flight Center, Greenbelt, Maryland. For

more information, see http://www.gvsp.usra.edu/gssp or contact: GSSP Program Coordinator, Universities Space Research Association, 7501 Forbes Boulevard, Suite 206, Seabrook, MD 20706; e-mail: GSSP@gvsp.usra.edu

June 7-July 16
REESS - Research Experience In Earth System Science, undergraduate summer research program at Norfolk State University from June 7 - July 16, 2000 to educate Science, Math, Engineering and Technology (SMET) majors in the visualization and interpretation of global climate change data. For more information, see http://vigyan.nsu.edu/reess.

June 11-July 21
Aurora Summer Program For Undergraduate Students, a six-week summer internship program for undergraduate students interested in pursing a career in Atmospheric Sciences. The program is jointly sponsored by Hampton University's Center for Atmospheric Sciences (CAS) and the NASA Langley Research Center. For more information, see http://ww2.hamptonu.edu/science/physics/AURORA/index.htm.

June 21-24
ESSEA Workshop at the Center for Educational Technologies (CET), Wheeling Jesuit University, Wheeling, WV. This workshop is limited to participating organizations in the ESSEA program. For more information on ESSEA, contact Claudia Dauksys, claudia_dauksys@strategies.org or see http://www.cet.edu/essea.

June 22-24
Climate Change Communication International Conference, University of Waterloo, Ontario, Canada. The conference will feature: Special sessions on Climate Change Education; Strategies to Engage Stakeholders; Public Understanding and Attitudes on Climate Change; Outreach Strategies. For more information, see the conference Website at: http://geognt.uwaterloo.ca/c3confer/.

July 9-14
Teacher Training On Applied Earth System Science, University of Pittsburgh at Bradford interdisciplinary workshop on Earth system science aimed at preparing pre-service education students and in-service teachers. Contact: Dr. Assad Panah, Director, Department of Geology and Environmental Science, University of Pittsburgh at Bradford, 300 Campus Drive, Bradford, PA 16701, e-mail: mailto:aap+@pitt.edu; Phone: (814) 362-7569; Fax: (814) 362-5088; http://www.pitt.edu/~aap/announce.html.

July 11-20
Interactions And Diversity: Earth System Science And Beyond, Puerto Rico. A workshop for PR and U.S. teachers, conducted by the Integrated Science Multi-use Laboratory (ISMuL) and the Puerto Rico Space Grant Consortium in collaboration with the Pennsylvania Space Grant Consortium. For more information, copy of the first circular and online application form are available at http://ismul.upr.clu.edu/interactions&diversity/webpages/index.html, or contact Ibis L. Aponte-Avellanet, Executive Director ISMuL, Associate Director PRSGC, University of Puerto Rico, Arecibo Campus, Call Box 4010 Arecibo, PR 00614-4010; Phone/Fax: (787) 817-4611; e-mail: ibis@adam.uprr.pr

July 24-28
IEEE International Geoscience And Remote Sensing Symposium (IGARSS '00), Honolulu, Hawaii. For details on abstract submission and any other information, please visit the conference Web site or contact: Ms. Tammy Stein, 17906 St. Emilion Court, Spring, TX 77379 USA; Phone: +1.281.251.6067; FAX: +1.281.251.6068; e-mail: tstein@phoenix.net; http://www.igarss.org.

July 30-August 4
Access Earth Teacher Institute, University of Southern Maine and the Wells National Estuarine Research Reserve. Teacher institute for high school teachers of students with disabilities. For more information contact: Nancy Lightbody at the the University of Southern Maine at (207) 228-8115 or 1-800-800-4USM extension 8115; TTY: (207) 780-5016; e-mail: nancy@lightbody.org.

July 31-August 4
S'COOL Summer Teacher Workshop, NASA Langley Research Center (LARC) Hampton, Virginia. Participants (teachers of grades 3-9) will be introduced to the Student Cloud Observations Online (S'COOL) program and work cooperatively in developing new materials related to the project. Contact the CERES S'COOL Project, Mail Stop 420, NASA Langley Research Center, Hampton VA 23681-2199; Phone: (757) 864-5682; Fax: (757) 864-7996; e-mail: scool@larc.nasa.gov; http://asd-www.larc.nasa.gov/SCOOL/

August 2-4
NASA Opportunities For Visionary Academics (NOVA) Professional Development Workshop, Colorado Springs, CO. Designed for education, science, mathematics, engineering, and technology university faculty involved in the education of future K-12 teachers. For more information about the NOVA workshop opportunities, please contact Lourena Richardson at (205) 348-3100, Fax: (205) 348-4171, or contact NOVA directly at: nova@coe.eng.ua.edu The application is also available at www.eng.ua.edu/~nova.

April 1 Marks 40th Anniversary Of First Weather Satellite

— Patricia Viets (Patricia.Viets@noaa.gov),NOAA NESDIS
— Cynthia M. O'Carroll (Cynthia.M.Ocarroll.1@gsfc.nasa.gov), Goddard Space Flight Center

The world's first weather satellite, orbiting at an inclination of 48.4° to the equator, was launched from Cape Canaveral on April 1, 1960. Named "TIROS" for Television Infrared Observation Satellite, it demonstrated the advantage of mapping the Earth's cloud cover from satellite altitudes. TIROS showed clouds banded and clustered in unexpected ways. Sightings from the surface had not prepared meteorologists for the interpretation of the cloud patterns that the view from an orbiting satellite would show.

Today, the nation's environmental satellites are operated by NOAA's National Environmental Satellite, Data, and Information Service in Suitland, Md. NOAA's environmental satellite system is composed of two types of satellites: geostationary operational environmental satellites for national, regional, short-range warning and "nowcasting;" and polar-orbiting environmental satellites for global, long-term forecasting and environmental monitoring. Both GOES and POES are necessary for providing a complete global weather monitoring system. Both also carry search and rescue instruments to relay signals from aviators and mariners in distress.

POES satellites monitor the entire Earth, tracking atmospheric variables and providing atmospheric data and cloud images. They track weather patterns affecting the weather and climate of the United States. The satellites provide visible and infrared radiometer data for imaging purposes, radiation measurements, and temperature and moisture profiles. The polar orbiters' ultraviolet sensors also measure ozone levels in the atmosphere and are able to detect the "ozone hole" over Antarctica from mid-September to mid-November. Each day, these satellites send global measurements to NOAA's Command and Data Acquisition station computers, adding vital information to forecasting models, especially for remote ocean areas, where conventional data are lacking.

GOES satellites are a mainstay of weather forecasting in the United States. They are the backbone of short-term forecasting or nowcasting. The real-time weather data gathered by GOES satellites, combined with data from Doppler radars and automated surface observing systems, greatly aid weather forecasters in providing warnings of thunderstorms, winter storms,flash floods, hurricanes, and other severe weather. These warnings help to save lives and preserve property. The United States operates two meteorological satellites in geostationary orbit, one over the East Coast and one over the West Coast with overlapping coverage over the United States. Currently, GOES-8 and GOES-10 are in operation.

In addition, NOAA operates satellites in the Defense Meteorological Satellite Program (DMSP), which are also polar-orbiting satellites. NOAA also manages the processing and distribution of the millions of bits of data and images the GOES and POES satellites produce each day.

NASA's Goddard Space Flight Center, Greenbelt, Md., is responsible for the procurement, development, launch services, and verification testing of the spacecraft, instruments, and unique ground equipment. Following deployment of the spacecraft from the launch vehicle, Goddard is responsible for the mission operation phase leading to injection of the satellite into orbit and initial in-orbit satellite checkout and evaluation.

On May 5, 1994, President Clinton made the landmark decision to merge the nation's military and civil polar-orbiting operational meteorological satellite systems into a single, national system capable of satisfying both civil and national security requirements for space-based remotely sensed environmental data. The new system is called the National Polar-orbiting Operational Environmental Satellite System, or NPOESS. Convergence of the civil and military programs is the most significant change in U.S. operational remote sensing since the launch of the first weather satellite.

The first converged satellite is expected to be available for launch in the latter half of the decade, approximately 2008, depending on when the remaining POES and DMSP program satellite assets are exhausted.

Graphics are available on the Internet:
First image is at: http://www.ncdc.noaa.gov/pub/data/images/tiros1.gif
First launch is at: http://www.photolib.noaa.gov/lb_images/space/spac0046.htm
NASA web sites:
http://goes1.gsfc.nasa.gov
http://rsd.gsfc.nasa.gov/goes/
http://poes2.gsfc.nasa.gov

EOS Science Calendar

June 20-22
AIRS Science Team Meeting, UMBC, Baltimore, MD. Contact Dr. H. H. Aumann, e-mail: aumann@jpl.nasa.gov.

June 27-30
Fourth International Conference on Direct Broadcast of Earth Observation Data, University of Dundee, Scotland. Contact Nicholas Kirby, e-mail: nekirby@dux.dundee.ac.uk; URL: www.dundee.ac.uk/dcczr/dbconference.htm.

Global Change Calendar

May 22-26
ASPRS: The Imaging and Geospatial Information Society, 2000 Annual Conference, May 22-26, 2000. Washington, DC. Call for Papers. For abstracts submission see URL: www.asprs.org/dc2000; tel. (410) 208-2855; Fax: (410) 641-8341; e-mail: wboge@aol.com.

May 30-June 3
AGU 2000 Spring Meeting, Washington Convention Center. Contact: (202) 462-6900; (800) 966-2481; e-mail: meetinginfo@agu.org, URL: www.agu.org.

June 12-14
Sixth Circumpolar Symposium on Remote Sensing of Polar Environments, Yellowknife, Northwest Territories, Canada. e-mail: circumpolar2000@gov.nt.ca, tel. (867) 920-3329, URL: www.gov.nt.ca/RWED/rs/circumpolar2000.

June 19-21
Sixth Biennial HITRAN Conference, Harvard-Smithsonian Center for Astrophysics, Cambridge, Massachusetts, URL: cfa-www.Harvard.edu/HITRAN.

July 16-23
International Society for Photogrammetry & Remote Sensing (ISPRS) 2000, Amsterdam. Call for Abstracts. Contact organizing secretariat, tel. +31 20 50 40 203; Fax: +31 20 50 40 225; e-mail: isprs@congrex.nl.

July 16-23
33rd COSPAR Scientific Assembly, Warsaw, Poland. COSPAR Secretariat, 51, bd.de Montmorencym 75016 Paris, France, tel. (33)-1-45250679; Fax: (33)-1-40509827; e-mail: COSPAR@PARIS7.JUSSIEU.FR.

July 24-28
IEEE 2000 International Geoscience and Remote Sensing Symposium, 20th Anniversary, Hilton Hawaiian Village, Honolulu, Hawaii. Call for Papers, For up-to-date data regarding submissions, access the conference website at URL: www.igarss.org.

July 24-29
International Radiation Symposium (IRS-2000), Saint Petersburg State University, St. Petersburg, Russia. For further information please contact conference coordinator, Evgenia M. Shulgina, St. Petersburg State University, Research Institute of Physics, 1 Ulyanovskaya, 198904, St. Petersburg, Russia; Fax: +7 (812) 428-72-40; e-mail: Evgenia.Shulgina@pobox.spbu.ru; or shulg@troll.phys.spbu.ru.

August 6-17
31st International Geological Congress & Scientific Exhibits, Rio de Janeiro. Contact Tania Franken, tel. 55 21 537-4338; Fax: 55 21 537-7991, e-mail: geoexpo@fagga.com.br, URL: /www.31igc.org.

October 9-11
First International Global Disaster Information Network (GDIN) Information Technology Exposition & Conference, Honolulu, Hawaii. Contact: dehring@erim-int.com, tel. (734) 994-1200, URL: www.erim-int.com/CONF/conf.html.

October 9-12
SPIE's Second International Asia-Pacific Symposium on Remote Sensing of the Atmosphere, Environment, and Space Sendal, Japan. Contact SPIE, URL: www.spie.org/info/ae/.

October 16-20
ERS-ENVISA Symposium "Looking at our Earth in the New Millennium," Gothenburg, Sweden. Call for Papers. Contact Prof. J. Askne, e-mail: askne@rss.chalmers.se; URL: www.esa.int/sympo2000/.

October 16-20
Ocean Optics XV, Musée Océanographique, Monaco. Contact Trudy Lewis, Lewis Conference Services International, Inc. Richmond Terminal, Pier 9, 3295 Barrington Street, Halifax, NS B3K 5X8; tel. (902) 492-4988; Fax: (902) 492-4781; e-mail: trudy@satlantic.com; URL: raptor.ocean.dal.ca/~optics.

October 24-26
Tropospheric Aerosols: Science and Decisions in an International Community—A NARSTO Technical Symposium on Aerosol Science, Querétaro, Mexico. Contact: Norman Mankim, tel. (775) 674-7159; e-mail: normanm@dri.edu; URL: www.cgenv.com/Narsto.

November 6-8
14th International Conference and Workshops on Applied Geologic Remote Sensing, Las Vegas. Contact: wallman@erim-int.com, URL: www.erim-int.com/CONF/GRS.html.

November 22-24
5th Fall Workshop, vision, modeling and visualization 2000, MPI fuer Informatik, Im Stadtwald, Saarbruecken, Germany. Contact Prof. Dr. Hans-Peter Seidel, tel. +49-681-9325-400; Fax: +49-681-9325-499, e-mail: hpseidel@mpi-sb.mpg.de.

April 8-11, 2001
GWXII: The XIIth Global Warming International Conference & Expo, 2001 Annual Conference: KYOTO COMPLIANCE REVIEW. Cambridge University UK. Call for Papers. For abstracts submission see URL: www.GlobalWarming.Net; tel. (630) 910-1551; Fax: (630) 910-1561; e-mail: gw12@GlobalWarming.Net.

Code 900
National Aeronautics and
Space Administration

Goddard Space Flight Center
Greenbelt, Maryland 20771

Official Business
Penalty For Private Use, $300.00

Bulk Rate Mail
Postage and Fees Paid
National Aeronautics and
Space Administration
Permit G27

The Earth Observer

The Earth Observer is published by the EOS Project Science Office, Code 900, NASA Goddard Space Flight Center, Greenbelt, Maryland 20771, telephone (301) 614-5559, FAX (301) 614-6530, and is available on the World Wide Web at eospso.gsfc.nasa.gov/or by writing to the above address. Articles, contributions to the meeting calendar, and suggestions are welcomed. Contributions to the Global Change meeting calendar should contain location, person to contact, telephone number, and e-mail address. To subscribe to *The Earth Observer*, or to change your mailing address, please call Dave Olsen at (301) 441-4245, send message to dmolsen@pop900.gsfc.nasa.gov, or write to the address above.